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Fifth National Conference on WHEAT UTILIZATION RESEARCH

Fargo, North Dakota
November 1-3, 1967

Agricultural Research Service
United States Department of Agriculture

THE FIFTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH was held in Fargo, North Dakota, November 1-3, 1967. Dr. H. R. Albrecht, President of North Dakota State University, welcomed the attendants.

The objective of the wheat utilization research conferences is, as expressed by Director Arlon G. Hazen of the North Dakota Agricultural Experiment Station, in his introductory remarks, to provide "a method of communication and a sounding board for all segments of the wheat industry--producers, millers, bakers, export and domestic marketers, and research workers whose studies bear on the complex subject of wheat--an opportunity and a sounding board to meet and to exchange information, ideas, and prophesies for the future."

Sponsors of the Conference were Agricultural Research Service, U.S. Department of Agriculture; Great Plains Wheat, Inc. and affiliated State agencies; Millers' National Federation; National Association of Wheat Growers; North Dakota State University; North Dakota State Wheat Commission and other State wheat commissions; and Western Wheat Associates, USA, Inc. and affiliated State agencies. Chairman of the Program Committee was Dr. R. J. Dimler, Director, Northern Utilization Research and Development Division, Agricultural Research Service, USDA, Peoria, Illinois. Chairman of Local Arrangements was Dr. K. A. Gilles, Chairman, Department of Cereal Chemistry and Technology, North Dakota State University.

Underscored numbers in parentheses refer to references at the end of each paper. The data presented in the references are essentially those supplied by the writer of each paper.

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FIFTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH
Fargo, North Dakota, November 1-3, 1967

INTRODUCTORY REMARKS

Arlon G. Hazen
Director, Agricultural Experiment Station, North Dakota
State University, Fargo, North Dakota

The National Association of Wheat Growers at Boise, Idaho, in December 1961 passed a resolution providing for a conference to be sponsored by the National Association of Wheat Growers, Western Wheat Associates, Great Plains Wheat, USDA agencies, and other interested groups to expand the use of wheat from our country in meeting the food budget requirements of the world through the regular export programs of our country and the Food for Peace programs.

Subsequently, a conference entitled, "The Role of Wheat in the World's Food Supply," was held at the USDA Western Regional Research Laboratory, Albany, California, April 30-May 2, 1962. This conference explored in some 21 presentations:

1. The World's Supply and Usage of Food
2. The Nutritional Values of Wheat
3. Opportunities for Marketing Wheat Abroad

Hatched from this embryo have been subsequent meetings designated as National Conferences on Wheat Utilization Research. It was originally conceived, and has been subsequently achieved, to utilize the conference medium as a method of communication and as a sounding board for all segments of the wheat industry--producers, millers, bakers, export, and domestic marketers, and research workers whose studies bear on the complex subject of wheat--an opportunity and a sounding board to meet and to exchange information, ideas, and prophesies for the future. While the conferences are not expected to set policy or dictate programs, they are expected to provide participants with a broad and necessary concept of the entire wheat industry. In turn, such understanding and concept can enhance better coordination and effectiveness among the various occupations and organizations which the participants represent.

The First National Conference on Wheat Utilization Research was held October 29-31, 1962, at Lincoln, Nebraska. Some 17 topics were presented and discussed. The Second Conference with its 26 topics was held October 28-30, 1963, at Peoria, Illinois. It was hoped to hold the meeting at the Northern Utilization Research and Development Division, ARS, USDA, but the attendance dictated use of larger physical facilities in Peoria for the meeting. Kansas State University was the site of the Third Conference, November 5-7, 1964,

where 25 topics formed the basis for the meeting. The Fourth Conference was held 2 years ago, November 3-5, 1965, at Boise, Idaho. Twenty topics filled the agenda.

Thus, as we open the Fifth National Conference on Wheat Utilization Research here in Fargo at the North Dakota State University we also embark upon a program containing some 20 specific topics oriented around the more general headings of:

1. Wheat and Food for Freedom
2. Protein and Food Needs
3. Wheat-Based Products for Overseas
4. A Technical Session on Wheat Quality
5. A Look at the Durum and Hard Red Spring Wheats

Even a casual perusal of the proceedings of past conferences cannot help impressing one with the diversity of topics and meaty content of the presentation. And there is every reason to believe those who have worked diligently during the interim since the last meeting have again provided a most tasty smorgasbord of topics from which each person in attendance may gain during the current conference.

I feel highly honored to be granted the privilege of opening this conference, and tremendously humble in the midst of this array of talent. At the same time, I call to your attention with great pride the importance of the wheat industry to this region of our nation and also the contributions of the many different kinds of people and organizations that are constantly helping to make the wheats of this area a truly significant part of the total wheat industry of the world.

If you are a first-time visitor to this area, and more particularly to this campus, we sincerely hope that during your stay and your participation in this conference you will more fully appreciate this unique wheat environment in which you are holding the conference.

I wish for each and every one of you a most successful and useful gain from the conference.

FOREIGN AID; WHAT'S NEXT?

Frank R. Ellis
Director, Food for Freedom Service, Office of War on Hunger,
Agency for International Development, Department of State,
Washington, D.C.

It is a pleasure and a privilege for me to appear before you today. I think you may find my topic, "Foreign Aid--What's Next?" intriguing--if you like suspense and mystery stories.

Some of the suspense arises from the current situation on Capitol Hill. If you've been following the news from Washington, you may know that the future of foreign aid seems to have the character of a mystery thriller.

One might say that our legislation is in the same plight as used to confront Pearl White in that silent movie serial, "The Perils of Pauline." Pauline was always in danger of a gruesome death at the end of each episode, but at the beginning of the next she was always saved in the nick of time.

Right now, we might well wonder--Will foreign aid be saved? Will the meat axe really chop off her head? And what is very much to the point for me and my colleagues right now is, "Who will pay the mortgage?" You may have heard that the Agency for International Development has had no money to operate for the past 10 days, which means that technically there's been no money for the payroll.

But--of course, we will get paid. And we can reasonably expect that there will be a bill passed before the year is out.

And, as in the films of old, our heroine Foreign Aid will survive--to suffer more adventures in the next episode.

There is more to it than that, however. The Perils of Foreign Aid cannot, like an old movie, be put out of mind when the lights go up, the piano player stops playing, and the audience goes home.

For our country--and that means all 200 million Americans--must live in a world of reality--not imagination. This great enterprise we call Foreign Aid is part of that world. What it accomplishes--and what it may fail to do--affects all of us. The kind of world our children will inherit depends on it.

Here is what I mean:

--Half of the 3-1/2 billion people in the world today are chronically hungry.

--By the year 2000, unless something is done to change the trend, there will be seven billion people in the world--most of them hungry.

--There is less food per person in the world today than there was a year ago. Unless something is done, this will grow steadily worse.

So, you see, the suspense is more than temporary. What will happen? Is our world to become a famine-ridden war-infested jungle, inhabited by billions of slowly starving people jostling and fighting each other for scraps of bread? Or are we going to find ways of producing more food and less people--and lay the foundations for peace?

Foreign Aid is the principal instrument we have to meet this great challenge. It might be a good idea to take a look at it to see what it is.

First, Foreign Aid is so familiar an aspect of United States international relations that it seems to have been with us always. Therefore, it may come as something of a shock to a taxpayer to be reminded that, as a part of our foreign policy, it is only slightly more than 20 years old. It was in June 1947, that Secretary of State George Marshall made his famous speech at Harvard that launched the successful Marshall Plan.

But what is foreign aid today? And what will it be?

Foreign Aid today is a vast, complex operation. It lends money, yet it is more than a bank. It writes insurance, but it is not an insurance company. It provides technical assistance and services, yet transcends simple charity. It provides guidance, but it's not a psychiatric clinic. It sells and donates food, but it is neither a super-supermarket nor a soup kitchen.

What many people forget is that Foreign Aid is really people. The rustle of money, the mists of theory, and the clouds of controversy often obscure this. I repeat--AID is essentially people, people helping other people help themselves.

I have in mind people like Ben Ferguson, an AID agricultural advisor who wades into the rice paddies of East Pakistan to show the farmers there how to grow more food.

Or, people like the humble farmer in Turkey who has realized the miracle of becoming the first in his family to own land--helped by AID to acquire it. And there is a former large landholder in Taiwan who has had to give up property that had been in his family for generations and is now a successful and happy businessman--helped by AID.

There are Indians who have existed for generations on the harsh Altiplano of Bolivia who are finding new lives and a richer future in more hospitable but hitherto unsettled regions of that country--thanks to American help.

All this is AID--all this is very human--and exciting. Perhaps the painstaking ascent of a poverty-ridden, illiterate people into a strong, dynamic nation hardly compares in suspense to the 10-9-8-7 countdown of a blast-off at Cape Kennedy. But we should keep in mind that the social and economic take-off of a new country, at the very least, is a major advance in man's progress, and we are not just spectators, but participants.

The intricate and precise functioning of a space camera on the moon is a marvel of sophisticated science. But there is something inspiring, too, in the earthbound picture of thousands of men and women in India, each carrying a basket of rocks up a honeycomb of scaffolding to build a great dam, so that some day they might have more water to grow food--and electric power to light a bulb in their huts.

This is the sort of thing that should be kept in perspective. There is a tremendous surge of human aspirations throughout the world and the American people are involved closely in it, largely through the vehicle of foreign aid.

But, how can we expect a better world--how can we expect the people of the less-developed countries to achieve more productivity, more education, more equality and opportunity--if each day more men die or are debilitated by hunger?

We can't. And that is why we now wage a "War on Hunger." This will concern--or should--dominate the U.S. foreign aid effort for the next 15 years, at least.

I have already referred in general terms to the great challenge we face: to bridge the gap between available food and expanding population. Here are some specifics, reported by the President's Science Advisory Committee, this past summer:

Food demand in the less-developed countries of the world is increasing 3 percent annually--

But--food production is increasing only 2.7 percent. Each year, then, the gap between what is needed and what is available grows greater.

At the same time, the per capita gross national product of these countries is increasing at a rate of from 0 to 1.5 percent. Per capita income is an average of $180 per year.

It is estimated that if the present population trend continues, an average of 52 percent more calories will be required in the world by 1985. In India, the requirement is 108 percent, in Pakistan 146 percent, and Brazil, 104 percent.

What are we going to do about this situation?

I have said that foreign aid is the principal instrument we have for meeting the challenge. Here is what we are doing in the Agency for International Development, the main organization responsible for administering U.S. foreign assistance.

AID has established an Office of the War on Hunger, to consolidate the staff activities of this complex and difficult effort. Within this Office have been established the Food for Freedom Service, which works with the Agriculture Department in sending U.S. food overseas; the Agricultural and Rural Development Service, which helps bring modern farm techniques to the underdeveloped nations; the Population Service, which is working on bringing family planning methods to the hungry countries; the Health Service; the Nutrition and Child Feeding Service, which is trying to upgrade the diets of people in the less developed countries; the Food from the Sea Service, which is attempting to increase the harvests of the oceans, and has already made important contributions through Fish Protein Concentrate, or FPC; and the Voluntary Foreign Aid Service, which works closely with international and voluntary agencies in fighting the War on Hunger.

In addition, AID has given the Office of Private Resources the responsibility of enlisting private firms and institutions in the War on Hunger.

The job is too big for our Agency, however. The job is, in fact, too big for the United States Government alone.

We are, therefore, enlisting the services of governments throughout the world. We need all the help we can get.

We know there is no one simple or easy solution. We know from experience in our own country the complexities of modernizing agriculture. It took us a span of almost a century. We haven't that much time to spare in getting the job done in the rest of the world. Our challenge is to speed up this modernization process--whatever it takes to get it done.

We are looking at general government policies and services, including budget allocations to agriculture; and decisions with respect to pricing and producer-incentives, land tenure, taxes, and agricultural credit.

We are paying greater attention to new technology, including research, extension education, with special attention to the development and introduction of improved seed varieties or breeds of crops and livestock and better practices for their production.

We are stepping up physical inputs for production, including fertilizers, pesticides, seeds and machines, with appropriate attention to their marketing, distribution, and cost as well as availability. We are going to need more adequate marketing systems, improved transportation and storage, and the creation of better processing facilities.

But above all, we are going to need involvement of farm people of the world themselves, continually seeking to help themselves.

What must be borne in mind is that the problem facing the world is not one of capacity to feed itself, but one of how this capacity can best be used.

Where we deal with human hunger, there is not one world, but two. The highly developed and highly productive world, and the hunger-ridden, under-developed world. The rich nations can produce so much more than they need that they can, and probably will, continue to be plagued with the possibility of surpluses.

In this connection we might note that the U.S. with its highly developed and highly productive agriculture must for the foreseeable future continue to operate domestic programs of supply/management to assure its producers fair prices for their products and incomes comparable to other segments of our society. At the same time we meet our responsibilities in helping less fortunate people, we cannot neglect our responsibilities to our own farmers.

Food aid may substantially increase in the time elapsing before the developing nations reach a stage of development where they can produce--or buy--enough food to give their people a decent living standard.

Our problem, then, becomes one of transferring American food to the hungry nations only on a basis of actual need, tied to demonstrable efforts at self-help by the recipient nations, at the same time that we transfer American know-how, adapted to local conditions and local traditions.

In the long run, we are creating new and larger markets abroad for the abundance of America. We are trying to develop trade through economic development.

Trade and development are two complementary, mutually reinforcing approaches to the world hunger problem. Inherent in the idea of trade is that both sides to any transaction must derive benefits. There is little point in trading with someone who has little or nothing to offer in return. But if you are able, at little cost to yourself, to help your prospective customer grow and develop, it should enable your business with him to grow and develop, with short-run and long-term benefits to both parties.

Until the day arrives when the economic disparity between the rich and the poor nations is lessened, we are taking steps to alleviate human hunger and to control population growth.

We have, in the Office of the War on Hunger, suggested some specific goals for the immediate future. For the 5-year period from 1967 to 1972, we will work toward these objectives:

1. An increase in the average caloric intake in the poor nations of 100 calories per person per day. (A total increase of 5 percent to 2,200 calories per person per day.)

2. Improved food quality by increasing protein availability by 5 grams per person per day. (A total increase of 15 percent from 32.5 to 37.5 grams per person per day.)

3. Increased food production or buying power to lessen the need for concessional food aid despite population increases.

4. Increase in the availability of agricultural requisites, particularly fertilizers.

5. Limitation of the overall population growth in the less developed countries to a total of 15 percent over the 5-year period.

6. Provide the opportunity for every AID recipient nation to seek U.S. help in adopting family planning programs.

7. Make preferred means for family planning freely available to all recipient nations which ask for help in population control.

8. Establish a nucleus of institutionalized scientific and technological capabilities in the high priority areas of agriculture, population, and nutrition, in each recipient nation.

This sounds like a huge order, and it is. Yet, if achieved these goals would do no more than meet the minimum needs set forth by the PSAC Report.

There are people who still ask: "should" we try to do all this? Or question: "Can" we? I do not wish to be an alarmist, but people more expert than I have forecast what will happen on this planet if we do not try to meet and surpass these goals of increasing food output, combating malnutrition, improving health, and curbing uncontrolled population growth.

The gloomiest of the prophets foresee chronic famine and widespread disease by 1975. The most optimistic see, at least, severe unrest, disruption and ever-growing threats to world peace.

So the question of "should" we commit our dollars and goods and services to this foreign aid program--War on Hunger--is really academic. The question of--can we do it--is irrelevant.

We must do it.

WHEAT AND FOOD FOR PEACE--AN EXPORTER'S VIEWPOINT

Daniel G. Amstutz
Manager, Spring and Durum Wheat Merchandising
Cargill, Incorporated, Minneapolis, Minnesota

Change makes people nervous.

This is the conclusion of Raymond Mack in a recently published study of the social impact of the technological revolution.

We can apply Mr. Mack's reasoning to our industry and say--"change makes commodity markets nervous."

By definition, in my judgment, such market nervousness is exemplified by the astounding range in wheat values during the past year. The difference between the "high" and "low" prices of Chicago wheat futures since mid September 1966 has been some 60 cents per bushel. This spread reflects about 40 percent of current Chicago wheat futures values.

And what has created this nervousness? Using our formula that "change equals nervousness," we can easily say that the factor of change has invariably been represented by the world food problem.

Over the past several years various reports of drought in the Southern Hemisphere, drought in India, drought in the United States, drought in Canada have usually resurrected the question--"is there enough food in the world to feed the hungry?" Conversely, realization of bumper production in the Soviet Union--as we witnessed a year ago, Australia's recovery last year from the previous year's drought, beneficial monsoons in India, and premature pessimism regarding this year's North American production--seem to provide a resounding "yes" answer to the question, "Is there enough food in the world?" Yes--at least for now.

As reports of "too little" or "too much" have been released, commodity markets--especially wheat--have swung like the pendulum on a grandfather clock. We have all learned that, in their own way, the economic ramifications of the world food problem are fully as significant as are the moral and social considerations.

When we talk of the world food problem, we are speaking of the less developed countries of the world. With very few exceptions, diet-deficit areas of the world are comprised of the less developed countries. Most of Asia, Africa, and much of Latin America can be so designated. Two-thirds of the world's people live in these areas. Their national average diets are nutritionally inadequate.

Over the years no nation has acted to remedy this chronic problem more forcefully than the United States. Our contribution has been "Food for Peace" or Public Law 480. Many feel that when the history of this period is finally

written, PL-480 will stand out as one of the most important measures ever enacted by the Congress.

Under PL-480 we exported 15.7 billion dollars worth of food and fiber between July 1, 1954, and December 31, 1966. An additional 2.2 billion dollars worth was shipped under Mutual Security (AID) programs. Over this period, our food aid exports represented 30 percent of our total agricultural shipments. They went to some 115 countries--most of them less developed--having a combined population of some 1.7 billion.

Statistics alone don't begin to tell what the food aid program has meant to people of other countries--and to us.

Overseas, our shipments have helped vastly in preventing malnutrition, hunger, and even famine. Our shipments have helped to further economic growth of the less developed countries. Our shipments have helped weak countries reduce the tensions that arise from food shortages and have given them strength to resist subversion and aggression. Our shipments have demonstrated in Asia, Africa, and Latin America that, when it comes to agricultural production, the American free farm system far surpasses the regimented systems of Communistic countries. All of these benefits promote the overall foreign policy of the United States.

We, here, have also derived substantial economic dividends from PL-480. PL-480 shipments have given farmers an additional outlet for their products--and additional income. These shipments have kept surpluses from becoming unmanageable. They have given employment to labor and profits to United States business enterprises. They have given us important balance of payments help--in the calendar years 1960-1966, this nation saved 1.8 billion dollars by using foreign currencies instead of our own to pay embassy and other expenses overseas, and by bartering farm products for foreign goods and services.

So much for what PL-480 has accomplished. Let us turn our attention to the situation as it exists today and what the future may bring.

Last year, PL-480 was extended for 2 years--i.e., through December 31, 1968--by the Food for Peace Act of 1966.

The most important change in this legislation is its call for the food deficit countries to do more to help themselves. This self-help concept was stressed by the President when he presented the Administration's program. As the bill progressed through the Congress, both the House and Senate added provisions to strengthen the emphasis on agricultural development within the recipient countries.

Several reasons were advanced for such strong emphasis of the self-help concept.

One of these was to restrain the tendency of some developing countries to use our food aid as a "crutch" whereby they may depend on us for food while diverting their energies and funds to other purposes.

In this regard, there was the recognition that a nation cannot be truly independent unless it has command of its own ability to produce or acquire something as basic as food. Also, the simple ability to supply food to hungry people will not necessarily command the affection and support of those who need it.

Another, and far more compelling, reason for the self-help emphasis surrounded concern about the ability of this nation to continue supplying adequate food aid to developing countries, assuming certain trends of food production and population. Secretary Freeman underlined this feeling of uneasiness when he said, "projections show that if recent trends in food production and population growth are not changed, and if we were to attempt to provide the developing countries of the free world with enough food aid from the United States to meet even minimum caloric standards, our capacity to provide such food aid under present patterns and policies of agricultural production would be reached within 10 to 20 years."

So that events are kept in proper perspective, remember that the Food for Peace Act of 1966 was written, debated, and passed during one of those "change" periods I discussed at the outset of my remarks. This was a period highlighted by fear of "too little." Drought in India had followed drought in the Southern Hemisphere. We even had the same problem in the southwestern breadbasket of our own country. Wheat markets were strong and nervous. Change does make people nervous and at the time it appeared that the world-wide supply/demand ratio for wheat was undergoing dramatic change--that demand might exceed supply far sooner than anyone had expected.

I do not wish to infer that the self-help concept in the Food for Peace program is not prudent and wise. Indeed, I consider it necessary. And it is easy now to look back over the last year and state that immediate concern regarding food availability was premature.

I do think, however, it is worth noting that the timing of action implementation, based on future planning, tends to be greatly affected by current statistical and psychological factors. In other words, reports of "too little" tend to set into motion governmental machinery for increasing production. This can, in turn, give us the near-term situation of "too much," causing the governmental machinery to go into motion once again--albeit for a different purpose--which in this case would logically be geared toward reducing production. We have witnessed such a chain of events over the past several years.

Let us examine various factors of the future food problems which led to the inclusion of the self-help proviso in the Food for Peace program.

In recent years, economists and demographers have wrestled with increasing fervor over all the immense complexities of this problem. They have examined it in light of population trends, food consumption patterns, and food production projections. A wealth of this data has been published.

Population

Early reports on population predicted that world population would double by the turn of the 21st century, and that the world was adding 1 million people each week.

It was pointed out that the technological revolution had one critically important effect in the developing countries--a marked reduction in death rates. The President's Science Advisory Committee said that "this decrease in mortality has not, as yet, been followed by a decline in birth rates. Consequently, it has created something unprecedented in the history of mankind--very high rates of growth over areas of ancient settlements. The time required to double the population in most developing countries is 18 to 27 years--it is 55 to 88 years in most developed ones. The developing regions now contain about two-thirds of the world's human beings. By the year 2000, if present rates of population growth continue, there will be more than four times as many people in the developing countries as in the developed ones."

"If fertility does not change, and mortality continues to decline, the population of the world will increase from 3.3 billion in 1965 to 5 billion in 1985, or by 52 percent. With a 30 percent decrease in fertility over the next 20 years, the world population would still be 4.65 billion by 1985--an increase of about 40 percent above 1965."

The Economic Research Service of the USDA has reported similar findings. They project an annual population growth rate of 2.5 percent between now and 1980 in the less developed countries. There are some who say that world population can and will be stabilized within another generation.

For example, Dr. Donald J. Bogue, Director, Community and Family Study Center at the University of Chicago, recently said, "The world is currently being swept by one of the greatest mass movements in all history--a unanimous movement to take emergency action to reduce human fertility quickly to within the limits needed for orderly human progress toward generally accepted social and economic goals."

Dr. Bogue pointed out that in many world "trouble spots," birth rates have already started to decline. He predicted that "by the year 2000, world population growth will have slowed to zero, or a rate so nearly zero that it could easily be brought to zero."

Consumption

So much for the population explosion. What of food consumption trends?

Food consumption trends have properly been considered in light of the income explosion--the rapid rise in per capita income which is occurring, not only in the developed countries, but in many less developed areas as well.

In the developing countries we can expect a rapid increase in per capita food consumption--as per capita income rises. As spendable income increases, an increasing larger percentage of this income will be spent for food. For example, if a family in India has income of $100 today, perhaps $50 is spent on food and $50 on shelter, clothing, and other necessities. When this family's income becomes $150, perhaps $80 will be spent on food and $70 on other items. I do not pretend that this example is statistically accurate--the concept is correct, however.

As income trends continue to climb, the demand for grain rises dramatically.

You are all familiar with the classic dietetic pattern--demand for food in underdeveloped countries is for quantity--not quality or nutrient value. The underdeveloped countries are consequently cereal eaters--their protein is obtained from vegetable matter.

As living standards increase, as countries progress from the underdeveloped status to developing and developed levels, the quality of nutrient value assumes ever greater importance. Animal protein is, therefore, in greater demand and it takes more units of grain to produce animal protein than is necessary when cereals are utilized directly for human nourishment.

Stated another way, use of grain for direct consumption never seems to exceed 400 pounds per person per year. It takes 1,600 pounds per year to provide the higher protein diet common to the United States. It is easy to see how grain demand will increase as people in developing areas consume less grain directly and more as animal protein products.

The income explosion, therefore, creates competition for the same crop land between rich and poor. One is demanding more feed grains--the other more food grains.

Production

This brings us to the last area of study which the economists have examined--food production patterns.

The President's Science Advisory Committee flatly states the problem by saying that the bulk of the increase in food supply must come from increased production of farm crops. There are, of course, only two ways in which agricultural production can be increased:

1. By bringing more land under cultivation.
2. By increasing yields of land under cultivation.

Some early studies made the unrealistic assumption that virtually all of the necessary increased agricultural productivity to fill the expanding needs of the less developed countries would have to be accomplished by and in the United States. Some of the past hysteria about "unavoidable famine by the 1980's" probably emanated from such reports.

Today, it is generally conceded that other exporting areas plus the less developed areas themselves can appreciably increase output, in addition to the United States. Indeed, this must happen.

Let us look at the diet-deficit areas.

Until the present time, most of the increase in food production in the developing countries has been achieved by extending traditional farming methods over a larger area of cropland. Substantial opportunities remain to bring additional land under cultivation in the less densely populated areas of Latin America and of Africa. But the vast majority of arable land in Asia is already in use. While there are marginal possibilities for using small additional areas, it is clear that as the population continues to grow, the amount of cropland per person in the Asian countries will diminish progressively.

In Asia, therefore, a shift to increasing crop production by intensifying agriculture and using modern methods to improve annual yields on land under cultivation will be mandatory. Even in Latin America and Africa, the increasing cost of clearing additional land may well make it more economical in many regions to concentrate on elevating yields rather than expanding cultivated areas.

To increase yields, a major expansion of irrigation facilities will be necessary to make multiple cropping possible, independent of wide variations in seasonal rainfall. It also will be necessary to develop and utilize new, high yielding varieties of plants, to increase the use of fertilizers and pesticides, and to employ improved farm machinery. Increased capital investments and increased expenditure on the part of farmers will be required to make these tools of modern agricultural technology available. These are the techniques which have been employed so successfully in the developed countries to transform farming into a business.

I have just quoted the President's Science Advisory Committee again. They conclude by saying, "the transition from traditional farming to modern agriculture will be difficult and expensive for the hungry nations, but it is absolutely essential if their food needs are to be met. There is no 'alternative.'"

You are all aware that there are dramatic reports of positive action and positive results in the developing countries. A good example is the success of the wheat breeding programs in India, utilizing materials introduced from Mexico. Authorities in India have set a goal of an annual increase of about 4.5 percent in food production. This is a most ambitious program and necessitates immense human and physical investment. But we do hear optimistic reports.

Ralph W. Cummings, the man who headed the Rockefeller Foundation agricultural programs in India for nearly 10 years, recently said, "There is a revolution in agricultural production underway and an unprecedented

excitement, not only among the scientists and planners, but among a rapidly growing segment of the farm population. Those who have not had a direct on-the-scene contact with this phenomenon will find on revisiting India that they have to readjust their projections for the future. I have a high degree of optimism that India can and will balance its food budget within the next few years."

A leader of the Indian wheat breeding team recently told me that it was entirely possible that India could achieve self-sufficiency in wheat by 1970-71. Note, he emphasized he was speaking in terms of self-sufficiency relative to subsistence--not relative to total food demand. Without so labeling it, he recognized the realities of increased demand and consumption commensurate with increased income. And in India, greater agricultural productivity will provide much toward higher per capita income.

Conclusion

All studies and projections of the future must be based on many assumptions. Unfortunately, the probability of error is rather great. Nevertheless, conclusions must be reached. Here are some for your consideration:

1. Population. I believe that population control via a decrease in human fertility in the less developed countries will be more successfully accomplished than many today believe likely. I place great import on the keen awareness for the necessity of such programs by leaders in the countries most affected.

On the other hand, I question whether we have adequately anticipated increasingly lower mortality rates in the developing countries. It would appear that the combination of technological advancement and higher living standards would accentuate the downward trend of these rates.

It would, therefore, be foolhardy, in my judgment, to place too little faith in the demographer's projections. I consider it especially dangerous not to particularly note likely population growth in the developing countries.

2. Food consumption. Compared with the population explosion, the effect on food consumption of the so-called income explosion has received relatively little publicity. I think we will be hearing much more about this in the future. To me, the realities of this concept are evident. We should, therefore, translate this thesis into added increased future grain demand.

3. Food production. I have great faith in the technological abilities of the agricultural industry. We are seeing the first positive signs of real progress toward greater productivity in the developing countries. I realize that the needs for water, seed, fertilizer, pesticides, equipment, and farming know-how are staggering. But, likewise, it seems that the developing nations themselves fully recognize that increased productivity in their own lands is a must. And necessity is indeed the mother of invention.

Role of the United States

There is no doubt in my mind that the United States will continue to play a dominant role in the probable perpetual battle of the world food problem. But this will be a role which we can realistically afford.

Most of the technological advancements will have their birth here. Our great agricultural universities and the reservoir of technical knowledge they represent will continue to pay real dividends to the less developed countries.

Investment for the needed input factors in the less developed areas promises to be largely American. And here let me add that recognition of the desirability for a favorable foreign investment climate must be forthcoming from the governments of the developing countries. Technical knowledge is of little help without the needed monies for implementation of the various programs.

The Food for Peace program will continue to be the buffer for the developing areas. Shipments under this program will continue to make up the gap between demand requirements and production. For, while we may be hopeful about increased productivity in the diet-deficit areas, I don't believe anyone is so optimistic to say that continued and even greater PL-480 shipments will be necessary in the future. It is simply not likely that increased agricultural output in the developing areas can offset population increase and additional demand resulting from the income explosion.

Wheat has been the bulwark of the PL-480 program. While other commodities certainly have a role to play, it seems safe to assume that wheat will continue to be the primary commodity.

Actual shipments of wheat will depend on many factors, of course. However, it is not unreasonable to expect that total annual U.S. wheat exports will hit the billion bushel level sometime within the next 5 years. It is a demonstrated fact that this Nation's near term-productive capacity would justify such exports.

Note, I said that actual exports would depend on many factors. The enigma of the agricultural industry is that the unforeseen or unexpected occurs so frequently. The vagaries of weather, for instance, can cause disaster one year and plenty the next. The fact that the unexpected must be expected creates a dilemma for the planners. I alluded to this earlier in my remarks when discussing the changes which nervousness brings about.

Specifically, this year we are faced with comparatively abundant world supplies of wheat relative to demand. So much so that in spite of the self-help aspects of the revised Food for Peace regulations, our government is earnestly searching out new areas of PL-480 demand, evidently with little regard to self-help requirements. Apparently the sole objective is to bolster sagging wheat prices. There is "too much" today even though the

master plan shows the probability of larger commitments in the future.

Such situations are unavoidable, I suppose, so long as projections for the future are based on assumptions which can be, and often are, proved wrong. The particular example I have cited seems to be an error in timing--nothing more.

It does, however, point out the need for continued close scrutiny of all of the factors that make up the world food problem. We must guard against the all-too-easy pitfall of, having made detailed studies, assuming they are correct until the evidence may overwhelmingly point to different conclusions. We must always be on the lookout for telltale signs which may indicate unforeseen change is occurring. We must look for reasons why our conclusions may be wrong. Only in this way can we soften the surprise of change that causes the nervousness which the planners would like to avoid.

All of my remarks today have pertained to Food for Peace. Let me remind you that wheat farmers in this Nation have two other important markets for their product. The domestic mills and commercial foreign buyers.

Wheat breeders in India have a relatively easy job--all they seek at the moment are high yielding, disease-resistant varieties. Currently they need pay little attention to quality characteristics.

In this country, even when we pass the billion bushel export mark, it is safe to assume that our combined commercial export and domestic mill outlets will account for as great a percentage of wheat disappearance as will PL-480. And let us remember that, regardless of the needs of the diet-deficit areas, commercial world wheat markets promise to always be competitive. Every exporting nation is eager to capture the largest possible share of those hard currency markets which are so beneficial to any country's balance of trade and balance of payments position.

While we all applaud successful efforts to develop new, high yielding varieties for release in this country, let us be certain that these varieties possess those quality characteristics which will enable our various wheat-producing areas to maintain and expand outlets in commercial markets.

I imagine that, over the next 10 years or so, agriculture will go through more changes than any of us can envision today. If our "change equals nervousness" equation continues to be correct, we may be headed for many sleepless nights. It has been said that a stiff dose of understanding is one of the better cures for nervousness. Conferences such as this and good cooperation between all segments of our industry provide a good climate for greater understanding. I hope we have more of both.

ROLE OF WHEAT IN PRESENT OVERSEAS PROGRAMS

F. R. Senti
Deputy Administrator, Nutrition, Consumer, and Industrial Use Research
Agricultural Research Service, USDA
Washington, D.C.

So much has been said about the world's food supply, the shortages, the poor distribution, and so many other related considerations that it is difficult to find a fresh, impressive approach.

Likewise, so many at this conference have been so deeply concerned with wheat for so long that statistics regarding its world importance seem somewhat pointless.

Nevertheless, I think we forget; I think we often fail to appreciate fully just how important wheat is as a world food source. I think it is difficult to comprehend the enormous quantities of wheat that are produced and consumed in the world.

When someone comments that wheat and rice together provide half or more of all of the food calories eaten in the world, this seems a simple thing to understand. Wheat and rice are produced in about the same quantities. Wheat, therefore, provides about one-fourth of the food energy to run the world.

But, what does the size of the world wheat crop mean to you--10 billion bushels--270 million metric tons?

I submit that these are incomprehensible concepts to most of us. A few of you have, perhaps, seen 1, or 2, or 3 million bushels of wheat in one pile, but even you cannot really appreciate the import of all of those digits in the numbers just cited.

Let us, therefore, spread this big pile of wheat that we have collected back out into the countries from whence it came. Figure 1 shows on a map of the world the many places where wheat is grown. The number of dots indicates the intensity of production. Pretty impressive, isn't it?

A thing to note is that several of the concentrations of dots are in net importing countries--East Asia, West Asia, Central Europe. In fact, the traditional exporting countries, especially in the western hemisphere, do not show up very prominently. A corollary fact to think on is that, in 1964, the U.S. exported wheat to 127 different countries in some amount or other. Wheat certainly does get around!

Figure 2 provides another aspect of the world food supply to think about. This map shows the countries in which food shortages exist. It also purports to show a measure of the intensity of the shortages. This can be

Where wheat is grown around the world

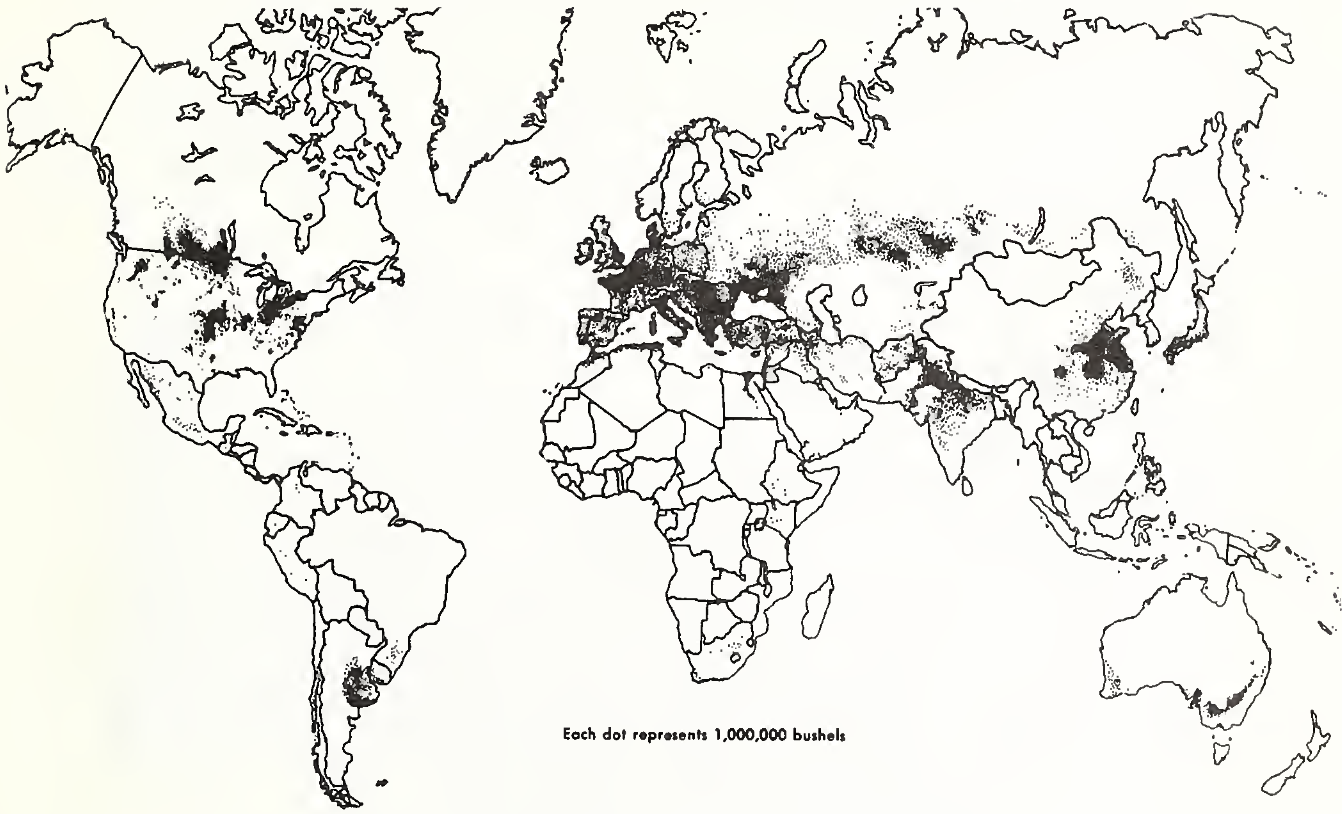

Figure 1

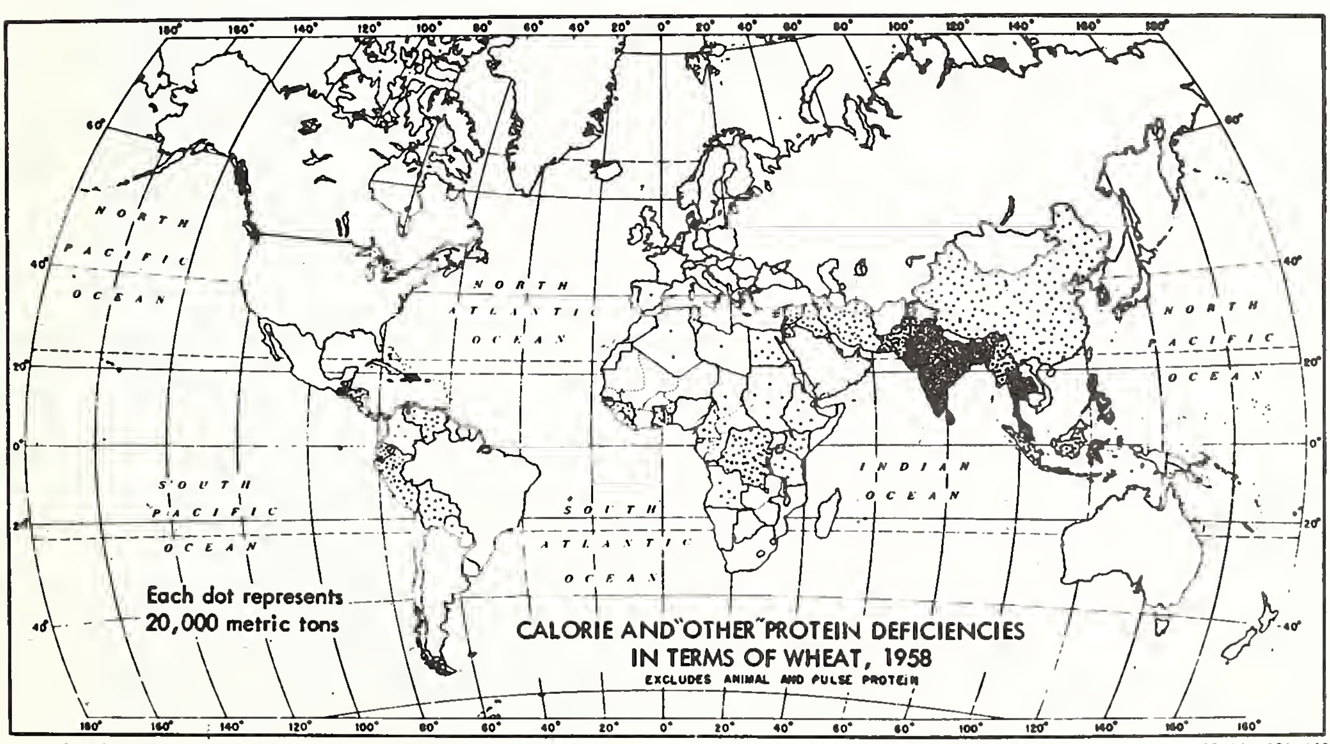

Figure 2

misleading because hunger and local shortages can exist in countries where the total food supply is reasonably adequate.

Now that we have seen how widely wheat is spread, let us consider for a moment how diversely wheat is used. We are all familiar with the wide variety of breads available to us in this country and most western nations, as illustrated in Figure 3.

Figure 3. U.S. bread products.

However, how many of us know of the type of bread common in China and in other Oriental countries, as shown in Figure 4? This is a yeast-raised bread, but instead of being baked it is steamed, so that no familiar brown crust forms. One Chinese name for this type of bread is mantou. The product is soft and yeasty and very good to eat. The speckled appearance of these rolls is due to bulgur that was mixed into the dough before steaming.

Other breadlike forms of wheat food eaten by a great many people in Pakistan and India are chapatties and tandoori; the latter is shown in Figure 5.

Figure 4. Oriental steamed bread.

Figure 5. Baking tandoori in Pakistan.

Here the flat, circular pieces of dough shown at the center of the picture are baked on the inside surface of a beehive oven below the surface of the platform on which these men are working. The highly puffed nature of the baked product is reminiscent of the flat breads common in Egypt, Lebanon, Syria, and other West Asian countries. Such flat breads are somewhat more sophisticated, however, because a small amount of yeast is added, and they are fermented before baking. Tandoori contains baking soda to raise them. Chapatties, which contain no soda, are otherwise similar to tandoori except that they are baked on a griddle instead of in an oven.

Contrast these simple baking methods with the highly sophisticated continuous-mix methods of dough production shown in Figure 6. Some 35 to 40 percent of the bread made in the U.S. is now made with such equipment.

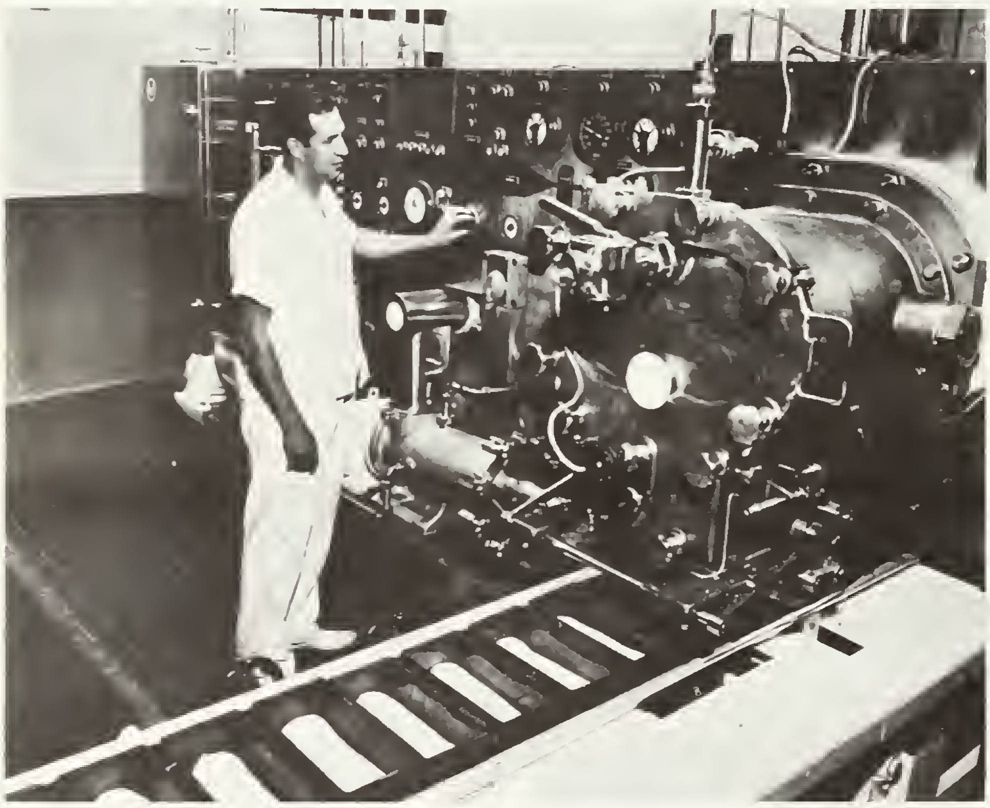

Figure 6. Main control panel of modern continuous process baking.

Breads of all of these kinds represent only one way that wheat is used for food. We are all familiar with the alimentary pastes such as macaroni, spaghetti, and noodles so common in southern Europe and countries around the Mediterranean sea. They are used very widely and have a long history. Enormous quantities of noodles, for example, are eaten in the Orient.

A moment ago I mentioned bulgur. It is a staple food in Near and Middle East countries. In North Africa couscous is widely used and is traditional. Dr. Johnston will tell you more about this wheat food.

Perhaps the simplest way to eat wheat is as a porridge. Most of you have eaten wheat in such a way--as rolled wheat flakes, as farina, or as mixtures with particles of other cereal grains in cooked breakfast foods to be served hot.

Toasted wheat flour, white or whole grain, is even used as a beverage in certain localities of some South American countries. In rural Chile wheat is made into a hominylike product by methods similar to those our forbears used to make hominy from corn.

Now that we have seen how widely and diversely wheat is used around the world, let us go back to the primary point and look at how U.S. wheat fits into our food aid programs overseas. We might begin by taking a look at our total exports of wheat in the several forms in which it is exported. Table 1 shows the cumulative totals of wheat and wheat flour that have been exported during the past 5 years--1963 through 1967. The totals have been broken down into a simplified way of showing the amounts under the various P.L. 480 programs. As you see, more than half of the wheat and a third of the flour was sold for soft currencies under the old P.L. 480 Title I. Still, more than a third of the wheat and about a quarter of the flour sold for dollars.

Table 1.--U.S. exports by program, 1963-1967

Category	Wheat, mil. bu.	Flour, mil. cwt.
P.L. 480:		
Title I	1,712.1	63.5
Title II	92.5	19.9
Title III:		
Donations	19.0	48.0
Barter	163.9	1.0
Title IV	183.1	5.1
Non P.L. 480	1,202.1	44.6
TOTAL	3,372.7	182.1

Table 2 shows the same sort of breakdown for bulgur and for rolled wheat. Here, we see that all but a very tiny amount of the bulgur was donated under Titles II and III of the old P.L. 480. Only 300,000 pounds was sold under Title IV on long-term credit. This occurred in 1963. None of the rolled wheat has been sold under any category.

Table 3 shows a very simplified breakdown of where our wheat was exported in greatest quantity in Fiscal 1965. First, the developed countries in this table represent, for the most part, our commercial sales abroad. In Eastern Europe, however, we still make some concessional sales, but these are rapidly going over to at least a long-term credit basis for dollar. Table 3 shows our exports in 1964-1965 to the developing countries--scattered pretty widely in South and Central America, in North and Central Africa, and in West, South, and East Asia. Among the Asian locations, India and Pakistan get the major share, as we are all aware.

Table 2.--U.S. exports by program, 1963-1967

Category	Bulgur, mil. lb.	Rolled wheat, mil. lb.
P.L. 480:		
Title I	--	--
Title II	434.1	38.2
Title III:		
Donations	1,492.4	358.9
Barter	--	--
Title IV	0.3	--
Non P.L. 480	--	--
TOTAL	1,926.8	397.1

Table 3.--Disposition of U.S. wheat and flour exports, 1965

Country	Wheat and flour exports, 1,000 bu.
Developed countries:	
Northern and Southern Europe	50,994
Eastern Europe	51,984
Japan	60,636
Developing countries:	
Central and South America	88,057
Africa	87,581
Asia	363,887

These general figures are not very revealing with regard to how important our wheat and wheat products may be in the food economy of some of these nations. Let us, therefore, pick out a few in each region and take a closer look at their situations.

For Asia, we need to look at either or both India and Pakistan because of the great magnitude of the problems there and the amount of our wheat going there. I have elected to include both because the two situations are not altogether parallel. Other Asiatic countries could very well be included, but I have not because of limitations on some of the data we need and because of limited space.

For Africa I have elected to use Egypt, Morocco, and Tunisia as these represent a variety of situations even though their geographical location is somewhat similar. For South America, I will use Chile, Brazil, and Colombia as fairly representative of the diverse situations in that part of the world. Let us look, then, at Table 4 to get an idea of their wheat supplies and sources. These figures are for the marketing year of 1963-1964, so may differ in totals somewhat for the last year or two, but the proportional imports are about the same except for Tunisia and Morocco. They recently have imported a greater quantity of wheat, most of it from us. The figures are very close to figures for 1959-1961, which is important to a point I will get to shortly.

Country	Production, 1,000 bu.	Total imports, 1,000 bu.	% Of supply from U.S.
India	362,300	171,448	30.6
Pakistan	155,740	62,278	27.9
UAR (Egypt)	55,100	69,267	55.0
Morocco	43,920	5,598	11.3
Tunisia	12,900	3,307	20.4

Table 4.--Wheat production and imports for 1964

Anyway, India and Pakistan grow quite a lot of wheat and import about half again as much--about a third of their total supply came from the U.S. Egypt imported in 1964 more than half of the wheat used, and most of it comes from the U.S. Morocco and Tunisia grow a much bigger share of their supply, and in this instance have imported all their extra wheat from us.

Going on to Table 5, we see that Chile grows all but a small amount of her wheat, but imports most of the rest she uses from us. Brazil imports much more than she grows, and half of her supply comes from the U.S. Colombia imports about twice as much as she grows and in this particular year, she imported two-thirds of it from the U.S.

Table 5.--Wheat production and imports for 1964

Country	Production, 1,000 bu.	Total imports, 1,000 bu.	% Of supply from U.S.
Chile	45,780	4,517	8.6
Brazil	11,000	76,913	52.7
Colombia	3,123	6,247	66.8

Table 6 shows that India and Pakistan get all of the wheat from us for soft currency and donations. Egypt bought about 15 percent of the wheat we sent to them, but Morocco and Tunisia were dependent on donations. In South America, Chile bought her wheat on credit; Brazil bartered and paid soft currency for most of hers; and Colombia was intermediate, paying dollars for much of it and bartering for most of the remainder.

Table 6.--U.S. wheat exports by program, 1967 (1,000 bu.)

Country	Commercial	Title I	Titles II and III	Title IV	Total
India	--	160,789	2,610	--	163,399
Pakistan	--	56,603	881	--	57,484
UAR (Egypt)	5,921	29,300	--	--	35,221
Morocco	--	--	2,671	--	2,671
Tunisia	--	--	3,059	--	3,059
Chile	--	--	--	2,990	2,990
Brazil	--	28,444	17,330	--	45,774
Colombia	2,058	--	2,615	1,129	5,802

Now let us go on to Table 7 to see what this wheat and wheat flour mean to the populace in these countries. From food balances worked out for the years of 1959-1961, we can determine that cereal grains provided from 60 to 72 percent of the food calories in these countries. The proportion

from wheat is much higher in the North African countries, however, than in India and Pakistan. This reflects the importance of rice and barley to the diets of these countries, when the whole country is averaged in. Northern India and West Pakistan account for most of the wheat usage, so that these regions have a much greater dependence on wheat than is shown here for the whole country.

Table 7.--Per capita consumption of wheat calories, average for 1959-61

Country	Daily calories from cereals, %	Cereal calories from wheat, %	Daily calories from wheat, %
India	63.2	17.9	11.3
Pakistan	72.3	28.1	20.3
Egypt	69.8	49.5	34.6
Morocco	59.4	51.3	30.5
Tunisia	57.4	84.6	48.6

Table 8 shows similar data for the South American countries. Note how important wheat is in the food supply of Chile compared to the other two countries where corn and rice are major sources.

Table 8.--Per capita consumption of wheat calories, average for 1959-61

Country	Daily calories from cereals, %	Cereal calories from wheat, %	Daily calories from wheat, %
Chile	49.3	88.2	43.4
Brazil	34.3	25.1	8.6
Colombia	32.1	16.9	5.5

When we calculate the contribution of wheat to the protein intake of these eight countries, we get somewhat similar percentage figures, but they run a little higher than for the calorie contributions. This reflects the higher protein content of wheat, on the average, compared to the other cereal grains.

By combining these several sets of data, we can estimate what proportions of calories and protein U.S. wheat furnishes to the food supply of these countries. Table 9 shows the pattern for calories and protein.

Table 9.--Total calories and protein from U.S. wheat, 1961

Country	U.S. wheat, % of total consumed	Daily calories from U.S. wheat, %	Daily protein from U.S. wheat, %
India	27.3	3.1	3.8
Pakistan	21.2	4.3	5.5
Egypt	44.5	15.4	16.5
Morocco	21.6	6.6	7.3
Tunisia	33.8	16.4	19.0
Chile	4.9	2.1	1.9
Brazil	47.3	4.1	6.0
Colombia	51.1	2.8	4.1

Several things are worthy of comment on this table. First, in spite of the huge quantities of wheat going to India and Pakistan in 1961, the contribution to calories and protein were quite modest. This is because they grow so much wheat of their own and eat large amounts of other cereal grains. The story is rather similar for the South American countries. Chile uses a lot of wheat, but grows so much of her own. Brazil and Colombia use a lot of corn and a relatively small amount of wheat. In Egypt and Tunisia, however, our wheat and flour made rather substantial contributions to their diets. The lesser values for Morocco reflect their own large wheat production.

Table 10 gives the same kind of information, but brought up to fiscal 1964. The contribution from U.S. wheat in India and Pakistan is up significantly, but still not very large. Figures for Egypt are up, but down for Morocco and Tunisia. All values for the South American group are up.

Table 10.--Total calories and protein from U.S. wheat, 1964

Country	U.S. wheat, % of total consumed	Daily calories from U.S. wheat, %	Daily protein from U.S. wheat, %
India	30.6	3.5	4.3
Pakistan	27.9	5.7	7.2
Egypt	55.0	19.0	20.4
Morocco	11.3	3.4	3.8
Tunisia	20.4	9.9	11.4
Chile	8.6	3.7	3.3
Brazil	52.7	4.5	6.6
Colombia	66.8	3.7	5.4

Values for 1965 would be up substantially for Morocco and Chile, because of greater imports from the U.S. Figures for Egypt and Colombia would be down, however, because of bigger local crops in one and reduced imports from the U.S. in the other. The remaining figures would be about the same. Adequate statistics are not yet available to determine what effect the drouth and our increased exports have had on our proportionate contributions for India and Pakistan in the past year and a half.

The small size of some of these percentage contributions can be misleading. For many people in these and other countries, our wheat food contributions undoubtedly provide a much larger proportion of their daily sustenance. Estimates of such figures would be very difficult to make, however. The wheat products such as flour, bulgur, and rolled wheat provided to the voluntary agencies under the old P.L. 480 Title III will very likely go to people for which these items provide a large share of their total food. A large part of the products will also very likely go to children, which brings us to the new types of wheat products developed expressly for the feeding of young children.

The new products are high-protein cereal products--fortified to have about 20 percent protein of good quality. This is a deliberate action and is for a very definite reason.

When we consider food aid in general around the world, the primary need is plain and simply for more food--for calories, in other words. Evidence is fairly good that adults and fairly well grown young people can get by quite well on the quantity and quality of protein provided by wheat--particularly if there is even a small contribution of animal, legume, or leafy vegetable protein in the general diet.

On the other hand, the protein requirements of young children and of pregnant women or lactating mothers are enough higher that serious consideration must be given to supplemental protein. They too, however, need calories badly, so that too high a level of protein in the diet would be wasteful.

The body's first call is for calories. If not enough are available, the body will burn protein for energy, rather than to produce new tissue or to maintain that already existent. Thus, a level of about 20 percent protein was selected for the special supplementary food products I want to discuss for you now.

The first of these is a protein-fortified wheat flour. Purchase specifications for the product were recently completed, and wheels are now in motion to obtain 5,000 tons of what is called Flour Blend A for India. An additional 3,000 tons has been requested for Iran.

The product consists of a blend of 70 parts of a straight-grade unbleached wheat flour and 30 parts of wheat protein concentrate, properly supplemented with vitamin A and extra calcium. A related product, Flour Blend B, consists of 70 parts of straight flour and 30 parts of unground wheat shorts. Purchase of Flour Blend B is contemplated for a later date.

General specifications for Flour Blend A are shown below. The total protein content of the blend is several percent above that of our regular export flour, but what is more important is that the biological value of the protein is higher. This is reflected by the minimum lysine content of 0.5 percent, as compared to the approximately 0.25 percent of the regular wheat flour. The quality of the protein is about doubled. There is also a significant reduction of crude fiber, which means more useful food in each pound. The vitamin and mineral contents of the blend are better than those of white flour, and the added vitamin A is entirely a plus value.

Partial specifications for Flour Blend 1/

Protein (N X 5.7), minimum	13.5%
Ash, maximum	2.8%
Crude fiber, maximum	2.0%
Crude fat, minimum	1.8%
Lysine, minimum	0.5%
Vitamin A, minimum	4,000 IU/lb.
Calcium carbonate, minimum	3.9 g./lb.

1/ 14% Moisture

The product is somewhat darker than white flour, but not as dark as whole wheat flour. It is usable for all kinds of breads, rolls, cookies, and biscuits. It can even be used for chapatties or tandoori, although the granulation is somewhat finer than desirable. Flour Blend B is better in this respect.

Before going any further, I should describe the wheat protein concentrate for you. The development and emergence of this new product have taken place since this group met in Boise 2 years ago. Dr. Johnston will also tell you more about this product and its uses.

As you know, when wheat is milled into white flour some 25 percent of the kernel goes into milling byproducts normally sold to the feed industry. The wheat germ and such protein-rich tissues as aleurone and outer endosperm go into the feed streams, together with the colored and fibrous outer bran tissues that have little food value for humans. The protein-rich tissues, however, have considerably higher lysine contents than the floury endosperm and are thus highly desirable for food uses.

Inexpensive techniques were worked out by scientists at the Western Regional Research Laboratory to recover much of this higher-value protein, so that it could be used in foods. Industry quickly took up the methods and improved them for practical application. Dr. Johnston will cover this aspect for you in more detail, I am sure.

The protein content of the concentrate will generally fall between 20 and 25 percent at 14-percent moisture. Preliminary cost estimates have fallen between 3.5 and 5.0 cents per pound.

Heavy usage of this new protein concentrate will not in itself move more bushels of wheat from your farms into commerce, but incorporation of the concentrate with flour, bulgur, or other wheat products will. The purchases and shipment of the protein-fortified products I will discuss will be, in general, over and above those for wheat and white flour normally made. A gain in total wheat movement will therefore result.

A second new wheat product for overseas use that I want to describe will probably be called Blended Food Product--Child Food Supplement--Formula No. 3. Purchase specifications are in late stages of review and approval. Purchases should begin in the very near future. Some 1,200 pounds of the product have already been sent abroad for preliminary acceptance testing, and clinical tests of its food value are now in progress with infants at a research hospital in Peru.

Blended Food Product--Formula No. 2 is popularly known as CSM. These initials stand for "corn-soy-milk." Many of you will already have heard of it and all of you will hear more from later speakers. The point is that processed corn meal is the primary ingredient in this Formula No. 2. Formula No. 3--the new one--will have as its primary ingredient, either straight-grade wheat flour or bulgur flour. These will be supplemented with defatted

soy flour, wheat protein concentrate, vitamins, minerals, and stabilized soy oil. The total contribution of wheat to both versions of the Formula will be 74 or 75 percent, depending upon how much soy oil is to be added.

The protein content of the blend will be 20 percent as a minimum, and the partly cooked product can be prepared for serving in no more than 2 minutes of simmering in hot water. The product may be made up into a crude beverage, into a gruel, or into a porridge by varying the amount of water used when preparing it. The product is frankly designed and directed toward use by children. The philosophy is that 100 grams, or 1/4 pound per day will provide an infant or young child with sufficient protein and essential food elements to escape the ravages of protein-calorie deficiency diseases. He may not prosper on such a small allowance, but he will survive in good enough health to become an alert vigorous adult capable of helping his nation solve their problems.

The final new product I want to mention as being near to commercial reality is a mixture of rolled wheat and of flaked, defatted soy grits.

As I showed you in an earlier table, we are already sending millions of pounds of rolled wheat overseas. By adding 15 percent or so of defatted soy flakes, the protein content of the mixture is raised to 20 percent. We can also add any desirable supplements of minerals and vitamins, although some technical decisions yet remain as to how this should best be done.

The mixed product is very palatable, well liked by those who have tested it, and usable in every way that rolled wheat is now used. Such a product could also be used in our domestic school lunch program in place of, or in addition to, the large amounts of rolled wheat presently used.

Wheat, wheat flour, and wheat protein concentrate are basic ingredients that can go into a great variety of food products, as we have already seen. Additional products are coming along, as will be described for you by Dr. Johnston and by Dr. Pence in their talks. The wheat protein concentrate can go into a great many conventional products, such as breads, noodles, macaroni, and so on. Many of the newer products already on the scene or on the horizon can eventually be made at point of use overseas from imported American wheat. Processing and equipment requirements can be adapted fairly simply in most cases.

Before closing, I want to mention briefly another way in which wheat can be improved as a food substance and on which utilization scientists have made significant developments. I am sure many of you have heard of adding the pure amino acid, lysine, to wheat or flour in order to improve the efficiency with which wheat protein can be used by humans. Wheat contains this essential amino acid in good quantity, but the level is not as high as is necessary for its total protein to perform its best under all use conditions.

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The addition of as little as 0.1 percent of lysine monohydrochloride to whole wheat will improve its efficiency of use by some 20 to 30 percent, as measured by rat-growth studies. This amounts to only 2 pounds of the amino acid per ton of wheat. Cost of the amino acid and its addition to whole wheat should not exceed $5 to $6 per ton. The possibility has aroused considerable interest among those concerned with food aid programs, as I shall elaborate on in just a moment.

Addition of the amino acid is very simple at the time flour is milled from wheat in modern flour mills. It can be metered in at closely controlled levels in the same manner as used for the normal vitamin and mineral enrichment factors. Where wheat is milled in village or home mills, as in India or Pakistan however, we have a different problem. Here the lysine must be added to the whole wheat kernel in a reliable, controlled way. The people at our Western Laboratory have worked out simple, inexpensive ways of infusing wheat with up to 15 percent of lysine. The heavily fortified kernels are then blended with untreated wheat to yield fortified mixtures that can only be identified by chemical or other special methods.

The government of India is interested in testing the value of adding lysine to wheat and is organizing large-scale experiments to measure possible effects on vigor and health of children receiving the fortified wheat. The Tunisian government is likewise interested in the addition of lysine to regular wheat flour. We in the Department of Agriculture will assist and participate in at least early stages of these efforts in any way that we are able to. The simplicity and low cost of this method of making our wheat more useful is very attractive. I expect that at the next Utilization Conference, I or another speaker can report to you some substantial progress in this regard.

In closing, I will not try to summarize the many points that I have covered. I think it is clear, however, that U.S. wheat has been a very important factor in sustaining the developing countries of the world. So many of them need all the help they can get in their different tasks of becoming stabilized and as self-sufficient as their situation allows. Many will become commercial customers for our food crops in due course, just as many of the more nearly developed countries already have become. I think it is also clear that the Department and the Utilization Laboratories have made quite significant contributions in this particular area of interest, as they have in many other areas of interest mutual to grower, processor, citizen, and government.

THE USE OF WHEAT IN INDIA

Richard K. Baum
Executive Vice President, Western Wheat Associates, U.S.A., Inc.
Portland, Oregon

Introduction. It is my pleasure to discuss with you "The Use of Wheat in India." The wheat growers have had an office and staff working full time in India since 1958 under a joint program with the U.S. Department of Agriculture.

Our program concentrated initially on furnishing technical assistance to the Government of India in the unloading, storage, and handling of wheat. I am pleased to report that the Indian Government has made real progress in these areas. More recently we have emphasized servicing to the mills and bakeries including bakers training schools. During all of this period we have carried out consumer acceptance and nutrition demonstration projects with local groups in the nonwheat growing areas of India. Housewives all over India now understand how to use wheat and flour. Prior to this time wheat had been grown and consumed primarily in the northwest one-third of the country

Population, size, and food habits. India has a population exceeding 500 million people living in a land area one-half the size of the U.S. At least one-third of the people are strict vegetarians and many more will only eat meat occasionally. This places a heavy dependence on cereal grains.

India needs to produce at least 90 million tons of food grains yearly to feed her people on a minimum diet. Her population increases now at the rate of 12 million per year, so each year the needs are greater.

Rice is the major cereal in India. Some 36 million tons of rice are produced annually compared to 10 to 12 million tons of wheat. Other major foods are grams, peas, millets, maize, and sorghum.

Fish, poultry, and meat are also consumed in India. The commercial fish catch is estimated at 1.2 million metric tons. According to experts 10 million tons could be harvested annually from the Indian Ocean without depleting stocks. Poultry numbers are estimated at over 150 million but feed is a problem. Goats supply the bulk of India's meat requirements. The slaughtering of cattle is prohibited by law in many states because of religious sentiments.

The per capita income of India in 1965-66 was estimated at $61.32. It is obvious that the people there must buy the least expensive foods.

About 75 percent of the people in India live in villages. A village, however, can number 200,000 people.

There is a serious lack of protein in the Indians diet. In a recent speech in Washington, D.C., the former Food Minister of India, Chidambaram Subramaniam said that "35 percent to 40 percent of the babies born in India each year eventually suffer some degree of brain damage. Indians, with their stomachs full of cereal grains, will still face the serious problem of protein starvation. Often those who are so afflicted are so stunted physically and mentally by the time they reach school age, they are unable to concentrate sufficiently to absorb and retain knowledge. We are producing millions of subhumans annually."

Before talking further about nutrition, let's review the production and use of wheat in India.

General information about wheat in India. All of the indigenous wheats produced in India are white. For that reason, the people have preferred white colored wheat. By law the locally produced wheat never reaches a flour mill. It is purchased as whole grain by the people and ground into a coarse whole wheat flour called atta.

The atta flour is used primarily to make chappatis. A chappati is like a flat unleavened pancake made from atta and water. Chappatis are cooked on single stoves in homes, over campfires in streets and alleys, and on the sides of earthen ovens. Often dried cow dung is the only source of fuel.

The consumers claim that red wheat atta makes their chappatis too dry and tough. The whole wheat flour also leaves an undesired red color. We have spent much time in India combating rumors and stories about the red wheat having undesirable effects on consumers. There is increasing evidence, however, that through repeated use, much of the prejudice against red wheat has been largely overcome.

About 25 percent of the wheat that is imported into India is allocated to the flour mills. They are only allowed to grind imported wheat. The flour mills produce both atta and the fine "maida" flour for the bakeries. The amount of flour for bread will expand as the food supply improves. Flour is often rationed to the bakeries. Six new modern bakeries are now being built in India under the Columbo plan as a donation from Australia. The use of wheat as bread, cake, pastry, or other western style products is largely confined to the urban areas.

The people in India eat mostly wheat they produce or what is produced in their immediate area. Processing, storage, and transportation are inadequate. Due to low incomes, the diet is very simple. It so happens that in the wheat-producing regions other food grains can usually be grown better than in the rice-growing areas; and therefore, the people have more variety of food and a better balanced diet. The people from the northern wheat-growing areas are usually taller, heavier, and healthier than those from the rice paddy regions in the south.

The average yield of wheat and other crops in India is very low. They plant 37 million acres or more to wheat but only harvest about 367 million bushels--an average yield of 10 bushels per acre. The low yields are the result of a variety of reasons; but it is clear that many of the older wheat strains cultivated in India have been selected more for resistance to drought and adverse conditions than for efficient performance under conditions of good irrigation and adequate soil nutrition.

Indian soil has been farmed for centuries with little use of fertilizer. The cow dung which was originally the main source of plant food is now used widely in the household for fuel.

The northwestern corner of the Indian subcontinent, between the Himalayan Range and the Hindu Kush Mountains, is regarded as the original home of the most important present-day cultivated species of wheat. Rice and sorghum are the only crops that exceed wheat in acres planted. In 1956-57, wheat accounted for nearly 15 percent of the area under cereals and 9 percent of the area under all crops.

Some of you may be surprised to learn that India was an exporter of a million tons of wheat per year at the turn of the century. Exports dwindled until World War II, when they stopped completely. The continual population increase, lengthening of the life span, disruptions due to establishing an independent nation, and neglect of the agricultural area are all factors contributing to the present food deficit position.

Classification by localities. For commercial purposes, wheat is generally classified under seven groups. This results in a large number of trade names. Some of these trade names are used to indicate different qualities while others are nothing more than synonyms. For example, the soft or semi-hard type grown in Aurangabad district of Maharastra State are known in the immediate locality as Potia (literally "spotted" or "motted") while the same wheat is called Sharbati in Hyderabad city.

Although soft and hard, white and red wheats are grown in adjacent tracts and sometimes even in adjacent fields, there is a fairly distinct localization of types. Each type has established itself in a particular tract or region and is found to do better in that tract than in most of the other areas.

The Roller Flour Mills. The Roller Flour Mills began in India in 1880. There has been a gradual growth of the industry. The mills were mainly located in the main wheat-growing states in the North and at the cosmopolitan population centers of Bombay and Calcutta. During the last 20 years, because of the scarcity of rice and the development of new industrial centers, the number of flour mills has been increased. The present economic condition of the 170 mills is not good because wheat is rationed to them. They only run at about one-third capacity. The present milling capacity is estimated to be about 4-1/2 million tons. The total consumption of wheat in the country,

based on the figures available for 1965 would be about 18 million tons. This includes 12 million tons produced within India and 6 million tons of imported wheat.

The Chakki Mills. The biggest use of wheat in India is in the form of atta flour. Most of this wheat is ground by Chakki Mills. A chakki mill is a grinder that consists of two circular stones which can be operated by manual or mechanical power. The use of hand-powered chakkis is rapidly declining. The use of camel and bullock driven grinders is also decreasing in favor of diesel and gasoline motors.

The roller flour mills also produce atta for sale and the demand of hotels and ordinary food shops is largely met by them. Generally speaking maida, suji, and rawa are produced on a commercial scale by roller mills only.

Primary wheat foods. In those parts of India where wheat is the major part of the diet, it is prepared primarily in the form of chappatis and parathas (chappatis cooked in shortening). Puris and kachauris (chappatis with filling and deep fat-fried) are other popular wheat preparations which are very frequently served for ceremonial and special occasions. In some areas these are consumed on a regular basis. In southern India, however, the common wheat preparation is uppuma (a form of semolina pudding). A similar product called rabri is used in central India. The use of paratha appears to be on the increase in southern India particularly in the bazaar food shops and for special occasions.

A number of other products, such as sweetmeats (halwa, kesari, etc.) and sewayan (fine vermicelli) are also made.

Atta flour is used generally for making chappatis, parathas, and kachauris but for puris and sewayan, maida flour is preferred. For the various sweetmeats both maida and semolina are used mixed or separately. Atta is rarely employed for this purpose.

The main preparations containing wheat products produced by halwais (Indian confectionery) are sweetmeats of various kinds and puris and kachauris. Many of the sweetmeats contain a high proportion of wheat products. For example, halwa or kesari may contain as much as 35 percent of suji. The ordinary food shops, however, prepare chappatis and parathas and other edibles for consumption usually on the premises. It is estimated that wheat is used in the following forms throughout India. Atta 60 to 70 percent, maida 20 to 30 percent, and suji 10 to 15 percent.

Yeast manufacture. There is one plant in India that manufactures bakers' yeast. Initially the marketing of bakers' yeast met with extreme resistance because the smaller bakers knew only the use of either hops or toddy (Palm juice) for the production of bread. Due to the efforts of a Wheat Associates sponsored mobile bakery demonstration project, the annual

production now of 1,200 tons of bakers' yeast falls short of the demand. The same company has plans to put up another bakers' yeast plant of 5,000-ton capacity.

Improving the baking industry. Some bakery equipment is now being manufactured in India, but there is a great demand for good quality bakery equipment like mixers, moulder, and slicers. A few companies are in the planning process of setting up plants that will manufacture bakery equipment in India.

Each month WA brings out a Bakers Informational Report which is distributed throughout India to a select list of several hundred bakers, all the flour millers, and to other allied industries. The excellent response indicates that the bakers are starved for information and are interested in improving their techniques.

The WA-sponsored School of Baking at Anand is equipped to train 16 students in each 20-week practical and theoretical course in baking suitable for Indian conditions.

This school of baking started operating in 1964 and to date has conducted six such courses which were attended by 52 students. Additional bakery schools will be required to turn out the trained bakers that are needed in the Indian baking industry which is now getting more recognition and impetus.

Wheat uses to expand. The six modern bakeries that the Government of India is setting up under the Columbo Plan will give an increased impetus to Western style bakery products in the larger cities which constitute people from all income groups. As economic conditions improve and as bakery products are continually made available at competitive prices, it can be expected that the sales will be expanded to the smaller towns and villages.

While the opportunity for the expansion of wheat products in the cities is very great, there is a much greater opportunity in the rural areas, where about 75 percent of the Indian population now lives. The greatest opportunity is in the traditional rice-eating areas. If this is to be accomplished, the wheat will have to be in a form that is acceptable, one that can be prepared with a minimum of equipment and heat. It is not likely that in the rural areas much wheat will be consumed in the form of bread for many years. A certain amount may be used in the preparation of confectioneries, but the great bulk of it will be used in the form of chappatis and similar products.

In the main, the baker produces bread known as dabal roti, though he also produces biscuits (crackers and cookies), cakes, and pastries. The biscuit manufacturers concentrate on the production of biscuits only. There are several specialized bakeries, confectioneries, and biscuit factories in the whole of India apart from numerous small bakers and biscuit manufacturers. Generally speaking, maida is used in these preparations. Some atta is used in making brown bread and certain forms of biscuits.

Uses other than food. The consumption of wheat flour in the form of starch by cotton mills for sizing purposes has declined considerably due to high prices and the need for food. Cheaper substitutes are now being used.

The amount of wheat fed to poultry, cattle, etc., is almost negligible. The poultry are sometimes fed on the screenings. Wheat bran is fed to cows, buffalos, and tanga ponies in the towns and cities. A certain amount of bran is sifted out from the atta produced by chakkis, but its quantity is relatively small. The main source of bran is the large roller flour mills.

Approximately 1.2 million tons of wheat are required for seed. It is estimated that cultivators retain about 70 percent of their seed requirements. With the setting up of a chain of wheat seed depots by the Department of Agriculture and the cooperatives, particularly in U.P. and Punjab, the tendency among the cultivators to purchase good quality seed has increased considerably in recent years. The average seeding rate for India is estimated at 80 pounds per acre.

Plans for self-sufficiency. The Government of India plans by 1970-71 to be self-sufficient in food grains. They hope to expand the production and consumption of wheat within India. They want to become exporters of rice to the Eastern European countries and use the foreign exchange to purchase wheat. One ton of rice today will purchase about 3 tons of wheat.

It is questionable that the Government of India will achieve their goal of self-sufficiency in food grains by 1971 due to the tremendous population increase each year. Great progress is being made, however, in the use of improved seed, fertilizers, and irrigation.

Importance of wheat protein for Indian diets. Before concluding these remarks, let's come back to the problem of protein deficiency. The following statement was prepared by Dr. Joellene Vannoy, Wheat Associates nutritionist, who has been based in India for 2 years.

> Protein in wheat can mean the difference between life and death for children in India more than in any other country of the world. Approximately 34 percent of the children between the ages of 1 and 6 years suffer from severe protein malnutrition. Such a thin thread ties them to life that a childhood disease, which rarely adversely affects children in the Western world, can terminate their existence. In addition, they are in such a weakened state that even 1 day's separation from their mothers will have a sufficiently profound psychological effect to cause them to expire.
>
> It has been estimated that 80 percent of the total protein in India is provided by cereals. Wheat, provides not only the biggest quantity of protein per serving, but also the best quality. Five years ago when nonvegetarians comprised half

of the population, there was a definite trend toward turning away from the vegetarian way of life. Now the trend has reversed itself, more because of the high price of animal proteins than because of religious beliefs. This places a higher priority upon wheat protein.

Recent research has proven that children short on protein foods, who survive the preschool period, are not only physically stunted, but may be permanently mentally retarded. The Government of India and U.S. AID are cooperating to develop children's food for the highly vulnerable preschool group. The first to be distributed on the market is called Balahar (which is the Hindustani word for children's meals). It is made of 75 percent wheat, 20 percent soybean meal, and 5 percent dry milk solids. Another type food is being developed with enrichment by the amino acid, lysine. Since wheat contains more of the eight amino acids essential for humans than any other cereal grain, it will be the first to have the addition of lysine. It will form the wheat protein into one commensurate with that from animal sources, which are considered superior because they contain all of the necessary amino acids.

Wheat protein is vital to the health of adults, too. Even though they no longer need it for growth, it is important in preventing infection and in keeping their bodies in a good state of repair. Women, who are pregnant or lactating, need greater quantities. Wheat protein is contributing much to the better health of Indian mothers. It also helps encourage better health among the fathers and older children in order that they may be better fit for work and study.

That is an excellent statement by Dr. Vannoy on the protein deficiency problem.

<u>In conclusion</u>. During the past 5 years the United States has shipped over 936 million bushels of wheat to India under PL-480. Countless more people would have suffered from hunger and many would have died from starvation if this had not been done. Irreparable damage would also have afflicted millions more children. United States wheat has played a great part in meeting India's food needs.

I hope now, that all of you have a better understanding of the uses of wheat in India. Western Wheat Associates will continue to work there under a cooperative program with Great Plains Wheat, the Nebraska Wheat Commission, and the U.S. Department of Agriculture. Our objective will continue to be to assure the most effective utilization within India of the wheat and wheat products received from the United States. In addition to that, our long range goal is to continue to assist India to improve her economy to where some day she will be an active trading partner in the free world community of nations and a cash market for our United States wheat.

IMPORTANCE OF PROTEIN IN WHEAT

J. A. Shellenberger
Professor, Department of Flour and Feed Milling Industries
Kansas State University
Manhattan, Kansas

Wheat is many things to many people. The full significance of this contention has been presented in a most effective manner by Drs. K. S. Quisenberry and L. P. Reitz (7) in the preface of the new book entitled Wheat and Wheat Improvement. The following is quoted from their statement: "Wheat is many things. To a botanist, wheat is a grass. To a chemist, it is organic compounds, and to a geneticist, a challenging organism. To a farmer, it means a cash crop, and to a hauler, freight. To a laborer, it means employment; to a merchant, it is produce. To a miller, it is grist, and to a baker, flour. The banker sees it as chattel and the politician as a problem. Animals browse and feed on it and it sustains parasites. The conservationist uses it as ground cover. In religion, it is used as a symbol. The artist and photographer see it as a model. To millions it provides a livelihood, and to millions more a lifegiving food."

The uniqueness of the proteins of wheat has been suspected since Beccari's investigations in 1745 (1) showed that the protein material separated from wheat could not be obtained from other seeds like barley or beans, and he marveled at the great differences in what he regarded as similar items. Even now, as we participate in the Fifth National Conference on Wheat Utilization Research, it seems apparent that the full significance of the importance of wheat protein has eluded many; including some who have attended these conferences in the past. The opinions and concepts of wheat protein held by the majority of persons associated with the nation's wheat economy remain untouched. Many darts of well conceived and excellently executed research work have been directed toward the wheat utilization target. Nearly all hit the target, but few hit the bull's-eye. Much more is known about wheat now than was known just a few years ago; yet one is hard-pressed to translate this knowledge into tangible results in terms of greater total wheat utilization.

Progress in the overall technology of wheat is tremendous. Great advances have been made in harvesting equipment and in the means for hauling, shipping, and storing wheat. Millions of bushels of wheat are brought together at terminal locations and segregated for special purposes. The selection of wheat by the processing industries is a highly developed science. The milling industry is equipped to produce any type of product that the market demands from wheat, and this ranges from breakfast foods, coffee substitutes, brewers' grits to industrial segregations of flour for every type of baked product. Special grain cleaning and particle-size regulation equipment is available and the control of starch damage, color, maturing properties, and diastatic activity, and vitamin and mineral supplementation is standard practice, and products are sold in attractive, appealing packages; yet the quantity of wheat used in the United States remains almost stationary. Considering the great diversity of competing foods, perhaps it can be

considered fortunate that wheat product utilization in the food category has remained nearly unchanged. It has required research, ingenuity, and devoted effort to prevent losing ground in the battle for an appropriate proportion of total food dollar to be spent on wheat products.

In dealing with wheat utilization, it appears that all too frequently our thinking becomes bogged down by tradition. We know that processed wheat has been a substantial food for man and animals since the dawn of history. It is difficult to contemplate modern society without wheat food products. Consequently, wheat utilization is intimately associated with food use; and industrial use has proved difficult to develop. There is need, therefore, to consider carefully and wisely why wheat utilization has been and remains tied closely with food use and why industrial uses for wheat have been difficult to achieve.

Wheat is unique from other cereal grains in only one respect, namely, its combination of proteins which permit dough formation and gas retention during fermentation. As illustrated in Figure 1, there are no outstanding

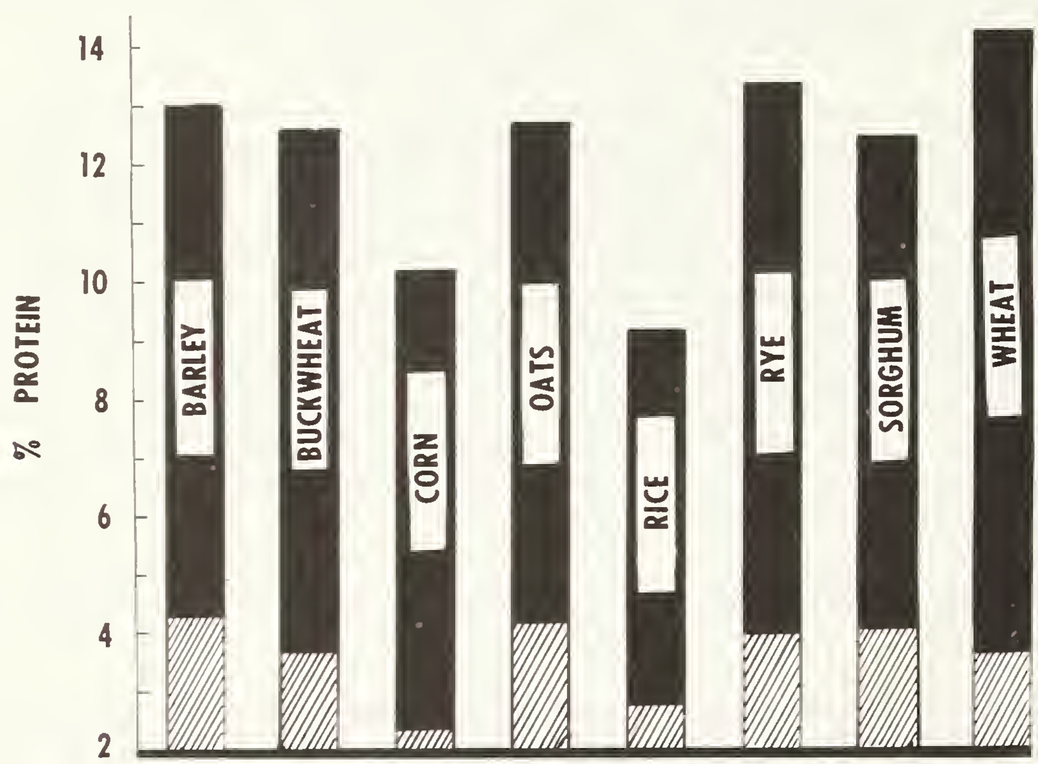

Figure 1.--Comparison of total protein content (N X 6.25) and the total of eight essential amino acids (crosshatched). Based on report entitled, Feed Composition (2).

differences in the protein quantities or essential amino acid distributions among the major cereal grains that account for the position that wheat has attained for food use. All grains are deficient in one or more of the essential amino acids. Broadly speaking, for food, feed, or industrial uses, there is great interchangeability among the cereal grains. There are major processing differences among grains but the proteins, carbohydrates, lipids, vitamins, and minerals possess great similarity. Wheat, however, is a commodity in the western world that is more highly regarded than other cereals for food use, and this is reflected in the price of wheat. Wheat is purchased mainly to be processed for human food. The special properties of wheat protein that permit the preparation of baked food products are what create the preference for wheat over other grains. There is a vast store of information on the chemical composition and physical properties of wheat, but as yet there is mostly ignorance of why wheat proteins behave as they do. All we do know and have known for many, many years is that wheat proteins are different.

Strangely enough, the recognition that wheat proteins are different has not been based on the wealth of scientific knowledge about the detailed composition and structure of the proteins. The proteins of wheat have been the subject of innumerable solubility studies following the work of Osborne (6). Various chromatographic and electrophoretic techniques, immunochemical studies, molecular weight determinations, and electron microscope patterns (4) have been reported; yet none of these procedures specifically shows why wheat proteins are so very special. The peculiar properties are explained only by the fact that about 80 percent of the total wheat protein forms gluten and gluten contains gliadin and glutenin, a combination of constituents that provide the basis for the use of wheat in baked products.

It is, therefore, inescapable that wheat continues to be grown and occupies a special place both in our domestic economy and in foreign trade because of the special protein characteristics that make it uniquely acceptable for the preparation of food products. Considering the importance of the protein content of wheat, it might be expected that protein would overshadow all other considerations, commencing with wheat breeding programs and continuing throughout marketing and eventual use. That, however, is not the case.

Sprague (8), in a recent review, states that average per acre yields of wheat have doubled in the past 30 years. In the Pacific Northwest, new semidwarf varieties have yielded 200 bushels per acre. Increased yields have resulted from improved cultural practices, disease resistant varieties, and fertilizer applications and the wheat plant has responded in a spectacular manner. However, in comparisons involving old and new varieties in the absence of disease, the newer varieties exhibit only moderate superiority in yield and probably no gain at all in protein content. About the best that can be said for the nutritive value of the proteins of wheat is that there is no evidence that wheat breeding programs have lessened its value. However, tremendous yields of low protein, high starch wheat are not a very practical achievement from either the viewpoint of use or nutrition. Starch can be produced more economically than by growing wheat.

Efforts should be intensified to improve the content of certain essential amino acids in wheat, and the recent increase in the lysine content of corn has been a great incentive (5). So-called high lysine corn contains about twice as much lysine as normal corn and since lysine is a limiting amino acid, when the protein source is derived from cereals, this is an important improvement. The lysine content is not the only composition change to occur, as electron microscopic studies have revealed changes in the protein network of the endosperm cells (10). There is a difference, also, in the zein content of the two types of corn and a known difference in grinding behavior (9). Perhaps we are on the verge of a development involving wheat proteins that will result in practical processing and nutritional changes in the composition and structure of the kernel. However, for the present, we must appraise in a factual manner what we really have accomplished. What, then, is the present situation?

A fair appraisal would be that little progress has been made in persuading the wheat plant to produce in the kernel proteins of improved quality or in greater abundance. The importance and significance of the protein in wheat does not receive the attention it should from wheat breeders, because protein, when obtained at the expense of yield, is objectionable to the wheat producer. Under present price support programs, a decrease in yield results in a decrease in income. In addition, protein content is not included in the official grade standards for wheat and is given little consideration in formulating international wheat agreements. Yet it is the amount and properties of the wheat protein that determine what food products can best be made from wheat. To produce cakes, cookies, biscuits, bread, or alimentary paste, there must be sufficient gluten to form a continuous protein phase. The extensiveness of this phase and its properties determine the type and quality of the baked product. Anyone who wishes to question this, needs only to try to bake bread without gluten or to try using a cereal other than wheat. It, thus, becomes paramount that greater attention be focused on producing more and better quality protein in wheat. As stated before, protein is the dominant reason for the food or feed use of wheat and therein lies its uniqueness among all plant or animal materials.

If the time ever comes when a substitute for gluten is produced, then the world wheat economy will undergo drastic changes that can be contemplated only with hardship for those whose welfare depends on wheat production, marketing, and processing.

To bring this discussion completely up to date, the current popular topic of alleviating hunger and malnutrition throughout the world must be mentioned and related to wheat and its nutritional quality. Hunger and malnutrition are scourges that have, from the beginning of time, plagued all forms of life. The theory promulgated nearly 170 years ago that population would increase geometrically while food production would increase arithmetically is apparently proving true. Secretary of Agriculture Freeman (3) has impressively stated the situation when he said the world food problem is a race between the production of food and the demand for food. We are prone to suppose that the food shortages in developing countries result

from a drastic lag in food production compared to the more developed countries; however, this is not a fact, since in the past 10 years food production has increased 19 percent in the less developed countries compared with 22 percent in developed countries. Thus, the increase in the rate of food production in the developing countries is not very different from that of the developed countries. Population growth rates in the less developed countries account for the food shortages. Therefore, the problem of hunger cannot be solved by food shipments, however well intended are our Food for Peace or Food for Freedom programs, because hunger will not be alleviated by this means nor will peace result. We are trying to correct a leak in a dike by putting our finger in the hole from the wrong side. The world population must be made to fit the food supply, and this country should not attempt to supply the food needs of the world. The most useful contribution this Nation could make to this serious problem would be a development to control population.

Dr. Milton Eisenhower, former President of Johns Hopkins University, is quoted as saying that foreign aid as this country has conceived and practiced it for a quarter of a century, is little more than a palliative, sometimes self-defeating. Nevertheless, since we are a philanthropic people, we are committed to food supply programs and other types of aid to foreign countries. The least we can do in the majority of cases where wheat supplies are concerned is to provide protein. Where malnutrition exists, there is also a deficiency of protein in the diet. Certainly, if we really have regard for the welfare of the people we are committed to help, we will not be content with exporting cargoes of low protein wheat merely because it is not needed in this country. If our wheat has to be supplemented with soybean or fish protein to meet minimum protein quantity levels, then wheat production has missed its goal by a wide margin because, for baking purposes, protein additives that do not provide gluten are only diluents.

Interest in and attention to the total nutritive value of the wheat kernel fluctuate like a yo-yo with the passing of time. Recently, interest has been on the upswing because of the need to alleviate hunger in developing countries. That the most nutritious portions of the wheat kernel reside in the outer kernel structures which are removed and discarded for direct human use during processing has been known and lamented for a long time. The desire to eliminate from food use the husk and outer bran layers of cereal grains has persisted for thousands of years. In ancient times, the hairs of animals were used to fashion crude sieves to remove the fibrous outer coatings of grains. In the course of the evolution of crushing or grinding grain, the procedures have ranged from saddle stones, slab mills, hourglass mills, querns, millstones, rolls, hammermills, and pin mills, and, no doubt, every conceivable type of alteration of particle size has been produced and investigated in one way or another for taste and palatability. Also, either intentionally or unintentionally, finely ground bran and similar products have been mixed with almost everything from honey to grease and tried as a food. The unfortunate situation is that it is most difficult to persuade people anywhere on earth to eat regularly and in quantity the byproducts of cereal processing. What is needed in this area are entirely new ideas, and the field does not appear too promising because the areas

where a new food development is needed most are also the areas where profitable sales are least likely.

Some of these comments and the attempt at a frank appraisal of wheat utilization programs could be construed as unwarranted criticalness or lack of sympathy for the aims, objectives, and accomplishments of the many wheat programs. Much excellent work has been done; wheat improvement results have been of great importance; wheat aid programs have alleviated hunger; and wheat has continued to be an instrument useful in making foreign policy. I do not wish to fall into the category described by Mr. Charles F. Kettering, former Research Director for the General Motors Corporation, who said, "Man is so constituted as to see what is wrong with a new thing--not what is right." There is much that is right with the wheat industry programs, but there is also much room for more imaginative plans. Imagination is a rather uncommon attribute of man, but what is needed for the future of satisfactory wheat programs are new ideas from persons with imagination and this is the challenge I wish to leave with you.

Nature has created in wheat a unique combination of proteins. Man has known for centuries how to make use of this uniqueness for his food uses. The urgent need now, before it is too late, is to build on the strength already achieved to create through research the quantity and nutritional quality of protein in wheat that will serve ideally the needs of man. In this complicated age man's needs are not just for wheat but for wheat that will serve specific purposes. The biggest, most critical, and most profitable market for wheat in the years ahead will be our own domestic needs.

Wheat utilization progress has been slow and only the surface has been scratched of what must be done to keep wheat products among the world's major food items. Everyone's support is needed for greater efforts toward wheat quality improvement.

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FISH PROTEIN CONCENTRATE, A SUMMARY STATUS REPORT

E. R. Pariser
Chief Scientist and Director of Engineering, Marine Resources AVCO Corporation, Wilmington, Massachusetts

I feel like a fish in a parched wheat field, amongst so many cereal experts; at the same time, I am very happy, and thank you for the opportunity, to be able to address this meeting today, even as an interloper.

There has, in the past, been a great deal of agitation about "fish flour," as it has been clumsily called; some people got the idea that fish flour was competing with wheat flour, that it was indeed, a dangerous competitor. Let me reassure you from the outset that this is not so, and that nobody in his right mind could possibly deny that for a long time to come, wheat and cereal products will remain the most important staple diets for most of humanity. Even if "fish flour," or fish protein concentrate (FPC), was far more versatile, less expensive, and more generally available than it is today, it would still be many years before this product could make the slightest dent on the world's wheat production and consumption.

FPC has still rather poor functional food technological properties, as we will see. It is only a food additive, just like lysine, but unlike the latter it is a complete protein with a broad amino acid spectrum. FPC cannot be used by itself. It has no baking properties whatsoever. It is essentially only a protein source.

Far from being a wheat competitor, I venture to predict that FPC will eventually help sell more wheat flour and other cereal products, just as we hope that the addition of lysine to wheat will do, because both these additives can be mixed to different foods in small, unnoticeable, but nutritionally significant quantities and improve the nutritive quality of the primary and major ingredient.

I. Definition and Significance

Definition

Fish Protein Concentrate (FPC) can be defined as an inexpensive, stable, wholesome product of high nutritive qualities, prepared for human consumption from whole edible fish by sanitary food processing methods. According to this definition, FPC is a product that is more concentrated in proteins and certain other components of nutritional importance than the raw material from which it was prepared.

FPC is intended for use solely as a high-protein food supplement, and may have various characteristics, ranging from tasteless, odorless, light-color

and flourlike materials, through coarse meals having a fish taste and odor, to highly flavored dark-colored pastes or powders resembling meat extracts.

This definition is quite arbitrary; it is restrictive and certainly not entirely satisfactory. It excludes, for instance, conventional fish meal, sun-dried, and salted fish as well as a number of other very important products which for reasons of sanitation or nutritional value, have been excluded. On the other hand, the definition includes certain highly flavored products such as fish sauces and pastes. The so-called biological methods leading to the production of these latter water-soluble and flavorful products promise an immense scope for valuable and diversified development.

Significance

The significance of FPC as a food additive becomes clearly apparent when viewed against the deepening world fooa crisis that we are facing. The present situation is due to many interrelated factors: A universal population explosion, more acute and more difficult to combat in developing countries; migration of populations to urban centers, depleting agricultural manpower, reducing agricultural productivity, and exacerbating already inadequate food distribution problems; a general shortage of purchasing power in developing countries, making it increasingly difficult for them to buy surplus foods from abroad; resistance of most population groups to changes in their food habits; a general absence of refrigeration or other food preservation facilities in most food-deficient countries, coupled to inadequate internal transportation systems and aggravated by a continuous and vast destruction of food due to insects and rodents; consumption of diets overwhelmingly based on single types of cereals and consequently a general lack of foods containing balanced proteins of high nutritive value.

Against the background of these conditions, the significance of FPC is clearly outlined. Establishment of industrial FPC endeavors and incorporation of FPC into diets of developing countries can contribute directly to improve the overall economic situation in general and the food situation in particular by: 1) Supporting and furthering to expand national fishing industries, thus increasing their purchasing power; 2) creating a new and diverse processing industry, new jobs and income; 3) utilizing a plentiful, natural, and hitherto incompletely exploited resource--fish; 4) producing an inexpensive food additive of high nutritive value which, because of its amino acid composition can, by the addition of small amounts to cereal diets, upgrade their nutritive value inexpensively without changing their organoleptic characteristics; 5) utilizing the whole fish as raw material, thus reducing processing costs and waste; 6) affecting the nutritional status of large numbers of people, irrespective of their geographic location, since FPC does not require either refrigeration or special handling or packaging and can be stored almost indefinitely if protected against excessive moisture.

II. History of Fish Protein Concentrate Manufacture

Fish spoil more rapidly than most other protein foods, such as meat, dairy products, or eggs. Procedures developed to inhibit growth of microorganisms and to prevent putrefaction of fish tissues are limited in number: with one or two important exceptions, drying, smoking, salting, pickling, cooling, freezing, and canning represent almost the total list of such methods, but all reflect the general desire to preserve fish as fish.

Processes involving change in the appearance and other properties of the raw food materials were early developed for the utilization of other foodstuffs. Wheat and corn, for instance, lose their identity by being processed into cereal; eggs and milk are drastically changed, becoming utilizable and unrecognizable in a large variety of foods. One of the oldest of man's staples, wheat, is still known by the name "triticum," a name related to the latin expression denoting the pulverizing process that is used to alter the product's original form and appearance. Many similar examples can be given. As far as the consumption of fish is concerned, the desire, with a very few exceptions, has almost always been to utilize fish qua fish.

The attempts, however, to produce protein concentrates from fish for human consumption is by no means a new idea.

Past Attempts

When Alexander the Great, in 325 B.C., traveled on the eastern shore of the Gulf of Persia, he came upon a people appropriately called "Ichthyophagi" or "Fish Eaters." Arrian, who gives an account of these travels, has the following notes in his records:

> Below the Gadrosians dwell the people called "The Fish Eaters".... thinking here to seize corn by force, Nearchus attacked the town, but the natives showed freely their flour, ground down from dried fish, but only a small quantity of corn and barley. Only a few of them fish, for few have proper boats or any skills; for the most part, it is the receding tide which leaves fish in pools which provide their catch. The more tender ones they eat raw, the larger and tougher ones they dry in the sun until quite sere and then pound them and make flour and a bread of them.

This is probably the oldest instance on record where an attempt was made to utilize a protein concentrate from fish as a food additive. This development can be followed in many examples through the centuries, leading finally to the numerous processes that have evolved in recent years and that are now based upon sound scientific principles.

Present Endeavors

It is almost axiomatic that the keeping qualities of foods in general, and of fish in particular, are directly related to the water content of the product: thus salting and sun-drying techniques were long ago developed for the conservation of fish and other foods. Such dehydration procedures, although not very efficient, have, over the centuries, had considerable success; the widespread usefulness of these methods is based upon the fact that the removal of water from plant and animal tissues causes certain chemical changes to occur and reduces enzyme action. Concomitantly, by sufficiently lowering the amount of free water in the tissues, microorganisms, that are ubiquitously present and responsible to a large extent for the processes that we recognize as decomposition and decay are prevented from growing and multiplying. The removal of water, then, just like the application of very low or very high temperatures for different reasons, is important for the establishment of bacteriostatic conditions. Another reason why drying has always been of importance is the reduction in weight and volume of the raw material, thus reducing transportation costs of the dried products. Thus, dehydration constitutes a means of preservation and is the first and perhaps the most important process in the preservation of fish.

Apart from water, which makes up about 80 percent by weight of most common species of raw fish, reference must be made to fish oils, fats, and related compounds which are present to the extent of 2 to 20 percent by weight.

These so-called "lipids" are of great importance because of their highly reactive nature, especially because many have the tendency to react with oxygen: under suitable conditions, certain lipids become rancid and can lead to the formation of compounds that are considered, by most, to be extremely unpleasant, and frequently reduce the nutritive value of the finished product.

In the simplest terms, then, an effective preservation of fish is based upon the removal of water and lipids from the raw material, or conversely, the isolation of a water- and lipid-free protein fraction. In practice, however, the picture is complicated because of the fact that the dehydration and defatting process must be so designed as to lead to end-products that have nutritional properties closely similar to those of the raw material. The processed material, to be useful, must of course, also be suitable for incorporation into different diets. A closer look reveals a number of unique and closely interrelated engineering and biochemical problems requiring intense and well-coordinated scientific research. We are, for instance, faced by proteins that can be easily damaged by a variety of causes but that we wish to preserve and separate from complex lipids and other components to which they are firmly linked; at the same time, a multiplicity of seemingly mutually exclusive processing requirements, needed to separate these components, have to be considered. We are faced by elusive problems of taste preferences and acceptability, by novel storage and transportation parameters, and delicate questions of digestibility of the products by infants and expectant mothers; there are

amino acid balances, physical characteristics, and a host of new economic and sociological problems to be considered.

As I have pointed out above, the foremost objective of an FPC manufacturing endeavor is the production of a stable food supplement of the highest nutritive qualities.

In order to achieve this aim, and to obtain a product in which the proportion of protein is significantly greater than in the raw material: a) Water and lipids can be removed from the fish solids by mechanical or physical means. The methods that were developed to this end can be grouped together under the heading of "Physical Processing Methods." b) To achieve extraction of proteins per se, chemical means including those induced by drastic pH changes can be employed to render the proteins water-soluble and extract them in solution; biological agents, such as enzymes and microorganisms, can also be applied to break down the proteins into smaller water-soluble units which are then separated from the raw material.

Methods achieving protein solubilization by the addition of acids or bases frequently cause serious damage to the nutritive value of the proteins and result in products of very limited nutritional usefulness. Procedures, however, that employ microorganism or enzymes, whether native to the fish or isolated from another source, have been used with some success in the large-scale manufacture of fish sauces and pastes in Southeast Asia. These methods can be called "Biological Methods of FPC Manufacture." c) Finally, in order to remove from the fish components that are either useless or that might directly impair the nutritive value of the protein concentrate, solvent extraction procedures have been developed. These methods are "Chemical Methods of FPC Manufacture."

I do not have sufficient time to review the many ingenious processes that have been developed in recent years. I feel, however, that I must give you a glimpse, at least, of some of the most important methods that have been put forward, and I have chosen these from the area of chemical extraction methods used in the manufacture of FPC. The goal that these methods have in common is the manufacture of an end product that is flourlike in consistence, bland in taste and odor, stable under ordinary storage conditions, of the highest possible nutritive value, and suitable for use in the supplementation of diverse diets especially those consumed by the very young children and expectant mothers.

1. Wiking Eiweiss. According to this process, developed in Germany during World War II, macerated whole fish is heated with stirring to 70° to 80° F. for 1 hour in an 0.5-percent acetic acid solution. After reducing the water content by pressing, the mass is extracted with alcohol and hydrolyzed with alkali; the protein solution is finally neutralized with acetic acid and then spray-dried. A pure, white, water-soluble powder is obtained and can be used as an egg white substitute. During World War II, the Germans manufactured and used several thousand tons of this material for human consumption.

2. Dabsch, V. Dabsch developed a process, utilized in a modified version in the UNICEF-sponsored pilot plant in Quintero, Chile, in which fish meal or comminuted fresh fish is extracted first with hexane and then with ethanol.

3. Vogel, A. G. The Vogel method incorporates pH changes of the macerated whole raw fish and uses ethanol as the extracting solvent.

4. Astra, Sweden. This process presently utilizes fish meal as the raw material but claims that raw fish can also be utilized. The principal feature of the process consists in the use of a polar organic solvent that is partly soluble in water and less dense than water, such as secondary butyl alcohol, normal butyl alcohol, and/or isobutyl alcohol. The extraction is carried out at a temperature somewhat lower than that of the azeotropic mixture.

5. The Viobin Process. This method of FPC manufacture was developed in this country a number of years ago and is covered by several U.S. and foreign patents. It is based on the use of two solvents: the first is a chlorinated hydrocarbon, ethylene dichloride; the second solvent is one of the lower aliphatic alcohols, preferably isopropanol. Extraction of the macerated raw material with the first solvent removes the water by azeotropic distillation, water vapors distilling over together with solvent vapors at a constant boiling temperature. At the same time that the raw material is dehydrated, the triglyceride and certain other of the lipid fractions become dissolved in the circulating solvent so that at the end of the first extraction stage, a dehydrated, essentially fat-free product is obtained. This intermediary material is reextracted in the second stage of the operation in which isopropanol is utilized to remove the rest of the lipid fraction and in so doing, deodorizes the product. Use of this method was approved by the U.S. Food and Drug Administration earlier this year for manufacture and sale of FPC in this country.

6. The Bureau of Commercial Fishery Process. This method, which was developed at the Technological Laboratory of the Bureau of Commercial Fisheries, U.S. Department of Interior, in College Park, Maryland, constitutes a further development of a manufacturing process that was devised and tested by the Canadian Fisheries Laboratory in Halifax, Nova Scotia, Canada. The BCF method is based on the use of one solvent only, isopropanol, to be used in two stages: one at room temperature, and the other at close to the boiling point of the solvent. The method is quite simple, and products made according to this procedure have been very thoroughly examined as to their chemical properties, nutritive value, wholesomeness, safety, etc.

This method was also approved by the U.S. Food and Drug Administration for use in this country.

III. FDA Situation

After a struggle that lasted over 10 years, the Food and Drug Administration finally approved in February of this year the use of fish protein concentrate as a food additive in this country. This approval was not granted without certain serious and far-reaching restrictions. Quite apart from specifying the chemical and nutritive properties of FPC, the government agency has stipulated that FPC could only be made from certain kinds of fish, namely hake and hakelike fishes. This measure was taken to prevent unscrupulous manufacturers from utilizing all sorts of trash fish or fish waste for the manufacture of FPC. Furthermore, bulk sales of the fish protein concentrate for use as an additive by food processors will only be authorized when data are provided that can demonstrate that the proposed use is not deceptive to the customer. As a further consequence of this ruling, FPC can, in the first place, only be sold to the final consumer in small, properly labeled, packages.

It is anticipated, of course, that further work will be done in this field so that other species of fish will be approved and utilized. It is also hoped that it will eventually be possible to incorporate FPC in reasonable amounts into other processed foods.

IV. Properties of FPC

As I have tried to point out before, FPC can be manufactured by a number of different processes, resulting in a great variety of products. These will, of course, have different characteristics, as far as their physical and chemical properties are concerned, but also as to their nutritive qualities. At the moment, the Food and Drug Administration has approved manufacture and sale of FPC in this country specifying precisely what raw material can be utilized and what process employed. The brief review of FPC properties that follows will only deal with the characteristics of products, made from raw material, and by manufacturing methods, approved by the FDA.

1. Physical Properties. Depending upon the method of final milling, FPC is a grainy, free-flowing, flourlike material. It has almost no hygroscopic tendencies and has been stored for up to 2 years in open containers under atmospheric conditions without lumping or showing other signs of excessive moisture pickup. According to the method of manufacture, the color of FPC is tan to light gray or creamy and does not tend to change during extended periods of storage.

The flavor and odor of FPC is difficult to describe and depends to some extent on the freshness of the raw material from which it was prepared. At worst, the finished material should have no more than a very faint fishy odor or taste but when prepared from fresh raw material under carefully controlled conditions, it is almost impossible for the uninitiated to guess what the material was made from.

2. Chemical Properties. The minimum requirements for the proximate composition of FPC are laid down in the regulations issued by the Food and

Drug Administration. The composition of the product that is usually produced by the approved method is, however, considerably superior to the limits required by the FDA: the lipid content of FPC is usually between 0.1 percent to 0.3 percent, the protein content usually between 80 percent and 90 percent, moisture between 4 percent and 8 percent. The ash content depends largely upon the fluoride level of the raw material and can vary between 5 percent and 13 percent. A representative amino acid composition of fish protein concentrate profile is given below:

Amino acid	% Of protein N X 6.25
Alanine	6.81
Aspartic acid	10.35
Arginine	7.13
Cystine	0.77
Glutamic acid	15.39
Glycine	8.09
Histidine	2.08
Isoleucine	4.56
Leucine	7.78
Lysine	8.41
Methionine	3.30
Phenylalanine	4.24
Proline	5.21
Serine	4.65
Threonine	4.47
Tyrosine	3.35
Valine	5.26
Tryptophan	1.03

3. Nutritional Properties. The nutritional properties of FPC have been determined in a large number of investigations, and I think it is fair to say that, nutritionally, FPC is equal or better than casein (milk protein). Again, the nutritional value of FPC depends to a large extent on the freshness of the fish and the degree of care and attention given to processing conditions. It has thus been possible to prepare FPC with a nutritive value very close to that of whole egg. A. Morrison, of the Canadian Food and Drug Administration, has pointed out in several publications that the nutritive value of FPC depends greatly upon the solvents used in the manufacture. The U.S. Bureau of Commercial Fisheries has carried out, and is presently devoting considerable attention to, investigations designed to establish the nutritive value of FPC when added to various staple food such as corn, wheat, and rice. Drs. Hammerle and Sidwell, of the Bureau of Commercial Fisheries have, for instance, supplemented Masa Harina, a lime-treated corn used for the preparation of tortillas, with FPC and with defatted soybean grits. These mixtures were steamed and fried and their nutritive value determined by rat feeding tests, protein

efficiency ratios (PER) being used as a nutritional yardstick. In these experiments it would seem that the PER of Masa Harina without supplement was 1.2. An addition of 5 percent FPC to the Masa increased the PER to 3.2. When the 5 percent supplemented Harina dough was steamed, the PER was found to be 2.8 and when the same dough was deep-fat fried at 350° F., the PER dropped to 2.7. When the same experiments were carried out with 5 percent supplementation of soybean grits to the Masa Harina, the figures reflecting nutritive value of the mixed products were 2.4, 2.3, and 1.8 for the simple mixture, the steamed dough, and the deep-fat fried product, respectively. The College Park workers were also able to show that an addition of 5 percent FPC and 5 percent soy grits to 90 percent Masa Harina raises the nutritive value of the mixture to 3.4, this value being reduced to 3.2 and 3.0 when the mixture was steamed and fried, respectively. A large number of experiments were also conducted in India where the supplementary value of FPC was established when it was added, together with groundnut flour and Bengalgram to a poor Indian rice diet. The proportions of groundnut, Bengalgram, and fish flours used were 2:1:1, this mixture representing 5 percent additional protein in the diet. In experiments with rats and young children, it was found that this kind of supplementation was very beneficial, increasing the nutritional status of the animals and the children very significantly. This, again, illustrates the exceptional nutritional value of FPC.

4. Functional Properties. There can be no doubt that the nutritional qualities of FPC are important, significant, and versatile, but it would be defeating the very purpose of our endeavors to neglect mention of the rather poor functional properties of the product as prepared today. There can be little doubt, also, that these properties play a very important role and will have to be improved very significantly, before a large industrial market for this product can be created. The lack of such functional properties is mainly due to the low solubility and hydration capacity of the product. Low wettability of the product tends to produce graininess which, in turn, makes it necessary to mill the final FPC to a very small particle size. Also, the residual slight fishy odor and flavor of FPC must be considered as a drawback, especially when bland products such as bread and noodles are to be supplemented. It must also, again, be emphasized that FPC has no baking properties whatsoever. In spite of the poor functional properties of FPC, a very large number of interesting foods have been prepared in which the presence of FPC contributed greatly to the nutritive value, without detracting from the organoleptic characteristics of the supplemented product.

5. Economic Aspects. It is at this stage premature to indicate at what price FPC could realistically be produced on an industrial scale. It must be anticipated that the product, especially if it has to meet the rather rigorous specifications of the Food and Drug Administration, will be rather more expensive than has been anticipated hitherto. The most important item in determining the cost of the final product will be the cost of the raw material, especially since the latter has to be of food grade quality and must, therefore be very carefully handled. The cost of FPC, also, will be determined by the

throughput capacity of the plant, larger capacities enabling the production of FPC at a lower cost. Initially, it is unlikely that FPC will be produced on a really large scale so that production costs will be rather higher than what is hoped they will eventually turn out to be. A realistic figure of 40 cents to 50 cents per pound, for a fully approved FPC (80 to 90 percent protein), manufactured in a plant processing between 50 to 100 tons of raw fish a day and turning out FPC at a yield of between 12 percent and 14 percent of the raw material, should be envisaged.

V. FPC As An Additive to Different Food Products

As I have pointed out before, a large number of different food products have been tested as to the effect of FPC supplementation. Only a few examples will be given here.

1. Bread. Dr. Sidwell, of the Bureau of Commercial Fisheries Technological Laboratory in College Park, has reported a number of experiments in which bread of the Vienna type was supplemented with FPC. In a series of tests in which wheat flour was replaced at the 5, 10, 15, 20, and 25 percent levels with FPC, Dr. Sidwell was able to observe a number of important effects. In the first place, the loaf volume of the supplemented bread decreased markedly with increasing FPC supplementation. The color of the bread deviated increasingly away from the white of the control loaf through a creamy color to light tan. The loaves with 5, 10, and 15 percent FPC appeared to be quite similar to the generally accepted high protein breads presently on the market; they also obtained highly acceptable ratings. Dr. Sidwell further observed that in order to bring the supplemented dough to the same degree of development as the control dough containing no FPC, it was necessary to increase the amount of water and to lengthen the kneading time as the amount of FPC increased in the formulation. It is worthwhile to point out here that a slice of bread weighing approximately 40 grams can contribute markedly to the protein intake of an individual: 2 slices of the 10 percent supplemented bread represent about 25 percent of the protein needs of a child; furthermore, the lysine and methionine contents of the bread almost doubled when 10 percent of the wheat flour was replaced by FPC.

2. Cookies. When various amounts of flour, utilized in the preparation of normal cookies were replaced by FPC, a very acceptable product was obtained although the cookies changed to a dull creamy color and the degree of sweetness in the cookies decreased with increasing FPC proportions.

3. Pasta Products. A number of macaroni products were prepared with FPC with very good results; it was noted that the color of the noodles was changed, although not unpleasantly, to a slightly creamy hue and the consistency of the noodles at the 10 percent FPC level became somewhat firmer than the control. The water absorption of both types of noodles (control and test) was about the same. Acceptability trials showed that these products were well liked by a great variety of people.

4. Liquid Products. A number of tests were made to incorporate FPC into freeze-dried soup preparations; although observations in this respect are still insufficiently conclusive, it appears that a very large and profitable area of new food formulation can here be opened up. This is especially true since the properties of FPC that are presently considered as unsatisfactory, can easily be masked by other ingredients.

Finally, a start has been made in the formulation of milk substitutes for baby formulas and very interesting results have been achieved especially when emulsifiers are used and FPC of a particularly fine grain structure is incorporated. A very acceptable product was obtained that could be dispensed in ordinary milk bottles and stored without settling out or clogging the nipple.

5. The Food Research Institute in Ottawa, Canada, has done a significant amount of work in the preparation of protein-rich food products incorporating wheat and fish. In this way, for instance, two traditional West African foods, Etoh and Fufu, were prepared with the assistance of a Ghanaian student. Etoh is a spicy mixture of yam with fish or groundnuts, whereas fufu is yam, cassava, or plantain prepared as a pasty mixture. FPC was incorporated in these products and the mixtures freeze-dried. Upon rehydration, these foods closely resembled the original food products; they were found to have excellent storage life and to be highly acceptable in West Africa.

Many similar products are beginning to appear in food research institutes and government laboratories; they indicate the general interest in the important supplementation capabilities of FPC for a wide variety of foods.

VI. Problem Areas in the Development of an FPC Industry

A review of the present status of the FPC picture would be quite incomplete, if some of the most important problems that remain to be solved were not mentioned here.

1. Raw Material. At the moment the Food and Drug Administration has only approved the manufacture of FPC from hake and hakelike species. It is, of course, necessary to investigate other schooling and edible fish for the manufacture of FPC and to obtain the necessary approval from the Food and Drug Administration. Although no great problems are anticipated in the utilization of fish like the herring and its relatives, care must be exercised in this respect since many properties of fish are liable to vary and new processing problems can be expected to arise.

2. Toxicity. It must be realized that out of the 20 or 25 thousand species of fish that are known today, 200 or 300 are known to be, or to become suddenly, bearers of potentially dangerous toxins. It is true that most of these toxic animals belong to solitary species, living in tropical waters. A few of them do not and are known to exist in temperate zones. It is likely

that many of the toxins are either water- or alcohol-soluble and can easily be removed for complete safety during the processing stages involved in FPC manufacture. The whole area, however, of toxicity must not be overlooked and represents a challenge.

3. Flavor. The chemistry of flavor precursors is one of the most complicated in organic chemistry. Flavor reversion in FPC, leading to products that have an unpleasant odor and taste, has been reported and must be studied in order to avoid negative consumer response. This is a problem area of great complexity but has to be handled for each species of fish that is used.

4. Acceptability. Finally, and most significantly, it must be borne in mind that the whole enormous investment that has been poured into the development of a safe and wholesome FPC, is of no avail whatsoever if the product is not accepted and sought after by those who need it most: the peoples of the developing nations. It has been observed that those populations that are in most dire need for food supplementation are most conservative as far as their food habits are concerned; enormous efforts are therefore required to give FPC the right image and market appeal and to overcome the religious, social, and other prejudices that are known to exist today in many parts of the world, in particular as far as fish products are concerned.

NEW PROTEIN FORTIFIED PRODUCTS USING MILL FRACTION CONCENTRATES

William R. Johnston, International Milling Co., Inc.
Minneapolis, Minnesota

One of the fascinating aspects of our business, research and development, is the interaction between technical knowledge and human need leading to increase of the former and satisfaction of the latter. The topic I am assigned to discuss with you today provides a fine example of this interaction at work. We have not yet written an end to my story, so you might say it is still a tale without an end, but that makes it all the more interesting because the challenge exists to write your own conclusion.

My story begins, arbitrarily, early in 1965 when a committee of the Millers' National Federation acknowledged a possible interaction between its objectives and a human need. The Millfeed Research Committee and its Technical Subcommittee, charged with responsibility to improve the commercial status of wheat millfeeds, recognized that these byproducts of wheat milling might help alleviate a predicted world shortage of protein for human food. Clearly, more information on their chemical composition and nutritional character was needed to facilitate their maximum utilization in food, and the two committees began planning a program to provide the missing data. Prior to this time, some evidence had already crept into the technical literature regarding the latent nutritive value of wheat millfeeds, and USDA scientists at the Western Regional Laboratory in California were already well on the way toward isolating a nutritious protein concentrate from wheat millfeeds. In late December 1965, Cap Mast, President of the Millers' National Federation, appointed a special committee with the assignment of providing government agencies, the milling industry, and others concerned with worldwide nutrition specific recommendations on how wheat and its products can be best utilized in feeding an expanding world population. The special committee, with Dr. Betty Sullivan of the Peavey Company as chairman, started its work in February 1966, by which time the USDA scientists had already published the results of their successful isolation of wheat protein concentrate (1). Shortly, thereafter, the Federation committee agreed to direct its major effort to formulating products based on the utilization of this low cost wheat protein concentrate. It was found that the concentrate could be blended with straight grade flour or Bulgur flour along with milk solids or soy flour and vitamins and minerals to produce a final product of about 20 percent protein of high nutritive value. At this stage, the efforts of the Millfeed Research committees bore first fruit in the form of a publication, and we may now reasonably expect further interactions to occur between new technical knowledge generated since 1965 and current human needs.

With this synopsis of the topic in mind, let us examine each of the interacting technical elements in turn. Beginning first, as is customary, with the technical literature, it has been recognized for many years that the aleurone and outer layers of the wheat berry have superior nutritive values,

in respect, particularly, to protein quantity, amino acid balance, and vitamin content. About 2 years ago, Dr. William B. Bradley, President of the American Institute of Baking, made the rather startling statement that the amino acid patterns of shorts and red dog are similar to the amino acid patterns of human milk (2). This is shown in Table 1. Dr. Bradley further stated that calorie

Table 1.--Essential amino acids of milk and shorts

Amino acid	Milligrams present in 100 calories of Human milk	Shorts
Isoleucine	100	189
Leucine	164	321
Lysine	119	238
Methionine-cystine	73	169
Phenylalanine	79	196
Threonine	82	173
Tryptophan	30	73
Valine	113	276
Arginine	73	390
Histidine	40	125
Total milligrams	873	2,150

for calorie shorts provide more than twice as much of the essential amino acids as human milk. He went on to say that shorts and red dog are also excellent sources of several of the B vitamins and several important minerals such as phosphorous and iron. In addition, shorts contain over 7 percent polyunsaturated fat similar to corn oil in nutritive value. Let me emphasize here that more than 5,000,000 tons of millfeed are produced annually in the United States, representing roughly 25 percent of the wheat milled. At this time, essentially all of the millfeed fractions produced are fed to animals. If, as seems feasible, 80 percent of the wheat millfeeds can be channeled to food uses rather than to animal feed, we would be able to increase the supply of wheat products for human consumption by about 20 percent--a most significant figure amounting, in the case of the United States alone, to almost 4,000,000 tons of food having about 500,000 tons of excellent protein. Used in the form of a supplement, this protein could meet half the requirements of about 30 million people.

Turning next to the activities of the Federation's Millfeed Research Committees, a program was designed to assemble all of the information available in the literature on the composition and nutritive value of wheat millfeeds, and to supplement the literature data with such new information as would be required to fully define the composition and nutritive value of millfeeds from the major classes of wheats milled in the U.S. today. After over 2 years of work, the first section of this ambitious compendium has just been published by the Federation as the MNF Millfeed Manual and is now available from the Federation. The Millfeed Manual will be completed in about 18 months

with the addition of two sections. The first section will cover extensive findings on the precise nutritive value of shorts, red dog, germ, and bran as determined by animal feeding tests, and the second will provide an economic evaluation of the findings. However, the first section of the Manual now provides invaluable information to anyone interested in utilizing millfeed fractions in Food For Freedom formulations.

At this point a brief review of the kind of information available in the Millfeed Manual may be helpful. The contents of this Manual represent an attempt to coordinate all existing information on wheat millfeeds, including information generated by the Federation's research program. The data have been expressed and arranged in a form designed to be understood by, and useful to, the scientist, processor, producer, businessman, consumer--all ~~who~~ are involved in the production and utilization of agricultural produce. Liberal use has been made of summaries, appendices, illustrations, and references to permit the reader to select any level of information dictated by his immediate professional interests. For example, the scientist will find precise definitions of materials and methods to satisfy his needs for scientific detail; the miller will find, expressed in terms familiar to him, the information he needs to relate the wheat products defined in the Manual to the products he produces at his own mill. The feed manufacturer, the nutritionist, the agri-businessman, and other members of the agricultural business community will likewise find information consistent with their professional disciplines.

The objectives of the Federation's millfeed research program have been outlined as follows:

1. To provide thoroughly characterized wheats, typical of the major classes of commercial wheats being milled in the United States today, which would serve as source materials for equally well characterized millfeeds;

2. To mill the wheats according to sound commercial practice, so that the milled products can be adequately characterized in terms of commercially milled products;

3. To analyze (physically, chemically, and nutritionally) the wheats and milled products according to the best scientific methodology available today, so that maximum reliability can be achieved by present standards of analysis;

4. To ensure the reference value of analyses by adequate description methodology;

5. To present the results in a manual within the framework of an exhaustive review of all aspects of millfeed technology; and

6. To make the manual available so as to encourage most efficient utilization of millfeeds by present technological standards and

to stimulate technological development toward maximum utilization of millfeeds.

Six commercial samples of wheat were selected to represent the major classes of commercial wheat grown in the United States in 1965. Four classes of wheat were represented in the sampling, the two major classes consisting of samples of both high and low protein to determine the effect of wheat protein content on the characteristics of the wheat millfeeds. This was the primary series destined for all analyses. A secondary series of three wheats of equal (intermediate) protein content was included chiefly to determine the variability in chemical analysis at a single protein level. A general description of the nine wheat samples is given in Table 2.

Table 2.--General description of wheat samples

Wheat designation	Protein 14% moisture basis	Test weight	Origin of sample
	N X 5.7	Lb./bu.	
Hard red winter low protein	10.8	63.0	Blackwell, Okla.
Hard red winter high protein	13.3	62.6	Burdett, Kans.
Hard red spring low protein	11.1	61.4	Choteau, Mont.
Hard red spring high protein	13.8	59.8	Valley City, N. D.
Soft white winter	9.2	64.4	Pullman, Wash.
Soft red winter	11.8	61.7	Winchester, Ind.
Hard red winter-1	11.5	61.2	Kans.
Hard red winter-2	11.2	57.9	Kans.
Hard red winter-3	11.9	57.4	Kans.

All of the samples were milled in the experimental mill at Kansas State University in accordance with good commercial practice to provide straight grade flour, bran, shorts, red dog, and germ. Complete details on the milling of the wheat samples have been published by Kansas State University.

In Table 3, the range of protein and yield values for the nine wheats and milled products are given to provide an indication of probable raw material variability for the production of the wheat protein concentrate used in the MNF Food for Freedom formulations.

The Federation is well aware that the Millfeed Manual, although broad in scope, presents information derived from one crop year, and it is somewhat hazardous to generalize from such data. Nevertheless, the following tentative conclusions have been drawn in an effort to summarize the findings and stimulate further studies.

Table 3.--Range of protein and yield percentages (14% moisture basis)

Item	Nine wheat samples	Straight grade flour	Bran	Shorts	Red dog	Germ
	N X 5.7	N X 5.7	N X 6.25	N X 6.25	N X 6.25	N X 6.25
Protein range	9.2 to 13.8	8.4 to 13.0	13.3 to 16.9	15.2 to 18.2	13.9 to 16.7	23.9 to 27.0
Yield (% of wheat)	--	72.3 to 77.0	12.5 to 16.9	6.6 to 8.9	1.4 to 4.7	0.6 to 1.1

1. In general, results of proximate analyses for wheats and millfeeds will not differentiate between different wheat classes. Even where a possible class distinction was observed in the present study (in low ash contents of Gaines wheat and its millfeed fractions), results of specific mineral analyses failed to verify the existence of a reliable class difference.

2. In general, protein contents of milled fractions (except germ) within a single class of wheat will vary as the protein content of the parent wheat, with shorts showing the highest protein content followed by bran, red dog, and flour. Relative protein levels in each of the millfeed fractions may be affected by the extent to which fragments of germ and endosperm enter the different millfeed streams.

3. When different wheat classes of widely different protein content are milled (separately), the corresponding milled fractions (except germ) will also vary as the protein contents of the parent wheats, independently of wheat class. Within each class, the descending order of protein content will be shorts, bran, red dog, and flour. However, anomalies may result when wheats of different wheat classes are similar in protein content, say within 1 percent. For example, a millfeed fraction from the lower-protein wheat might have a higher protein content than the corresponding fraction from the higher-protein wheat. Differences in milling performance (e.g., differences in purity of extracted wheat germ, or differences in distribution of wheat germ or endosperm particles among different feed streams) may be the chief reason for such anomalies.

4. In general, wheat germ appears to be remarkably constant in terms of protein, ash, and crude fiber, regardless of wheat class or wheat protein. Moreover, wheat germ is the least variable millfeed fraction in terms of amino acid composition, mineral composition, and vitamin composition. Much, if not all, of the observed

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variability in these analyses may be associated with variable quantities of bran and endosperm adhering to the germ. However, germ of hard red spring wheat seems to be significantly higher in total lipids than germ of other wheat classes in the present study. This difference in lipid content is reflected by relatively high values of oleic acid and possibly by low values of palmitic and linoleic acid (all in the saponifiable fraction). This suggests that genetic differences among wheat classes may perhaps be associated with characteristic lipid composition in pure wheat germ.

5. There is considerable variability in amino acid composition of each wheat, bran, shorts, and red dog, except possibly within a single wheat class at a single protein level. In this respect, millfeeds are no different from most other common feed ingredients. Nevertheless, these results can provide the basis for more rational use of millfeeds in human and animal feeding.

6. There are as yet no obvious class differences in mineral and vitamin contents. It is clear, however, that much of the mineral and vitamin content of wheat is concentrated in the millfeed fractions by the process of wheat milling. Thus, all millfeeds contain potentially useful amounts of minerals and vitamins. Minerals in nutritionally significant amounts include phosphorous, potassium, magnesium, iron, manganese, copper, zinc, selenium, and cobalt. Vitamins in nutritionally significant amounts include thiamine, riboflavin, niacin, pyridoxine, folic acid, pantothenic acid, alpha-tocopherol, and choline.

7. The possible role of lipids in characterization of wheat class is suggested by apparently significant differences in lipid composition between hard red spring wheat and other wheat classes. Although the lipid composition of wheat germ may be the source of class difference (as mentioned previously), there may be also class differences in the lipid composition of endosperm which might be associated with differences in the baking quality of flours milled from different wheats.

With this background of information on millfeed and its fractions, let us turn now to the production of wheat protein concentrate and its use by the MNF. As mentioned earlier, USDA scientists explored the possibility of isolating a protein concentrate by grinding millfeeds on rolls and subsequently sifting to obtain a product with lower fiber and higher protein than the original millfeed. The findings were promising and have been developed to a production scale by several millers. Reporting for the Federation's Committee, Dr. Betty Sullivan has published in Cereal Science Today (3) as follows:

> To obtain maximum yields and highest protein efficiency ratio and vitamin content, the type of wheat employed for the original milling is important. Most hard winter and hard spring wheats are satisfactory.

Soft wheats are less desirable because of their lower protein content and because they are more difficult to sift. Results likewise depend on the particular feed streams used for the initial grindings. Screenings are undesirable. The outer bran layers are lower in protein and higher in fiber and consequently are less valuable than the total millrun middlings or inner bran. Inclusion of the germ is recommended. Impact mills, and especially the Palyi Mill, using rotors with saw blades give better results than rolls from the standpoint of grinding efficiency and protein content of the finished product. Sifting gives better results than air separation. Products of higher protein content can be obtained by air classification, but yields are less. Of course, classifiers can be employed advantageously to remove a small amount of fines before sifting. The ground product usually is sifted through cloths ranging from 8XX to 12XX. Yields vary from 30 to 35 percent on the average wheat millrun middlings.

In Table 4 is shown the analyses of a wheat concentrate derived from hard winter, total millrun middlings (without ground screenings) of 15.5 percent protein and 8.5 percent crude fiber. This product was ground on an impact mill (Alpine 630-C) and sifted through a 10XX silk.

Table 4.--Analyses of wheat concentrate

Constituent	Percent
Moisture	10.5
Protein (N X 6.25)	23.0
Ash	3.9
Fat	5.0
Fiber	2.8

Analytical results covering amino acid composition and vitamin and mineral analysis have been published in the October issue of Cereal Science Today.

Using this type of wheat concentrate, the Federation's Committee developed three basic types of new wheat products which may be described as follows:

1. Protein Enriched and Fortified Flour Blends. Two types of blends have been developed, both consisting of a ratio of 70 percent hard wheat flour and 30 percent selected high protein shorts without screenings. In one type (described as Blend A), the 30-percent "shorts were reground and sifted, thereby producing a wheat protein concentrate, in order to increase the protein content and lower the crude fiber and to make a flour type suitable for general functional uses such as bread, cracker-biscuit, and pasta. In Blend B, the shorts were not reground. This type is darker in color and coarser and is designed for making chapaties or a gruel. Vitamin A and the mineral premix were added to both blends. For Blend A, bromate treatment was also included.

The flour blends have a protein efficiency ratio (PER) of around 1.3 which is substantially above regular flour. The protein value was raised by around 25 to 30 percent, or about the same as the amount of the shorts included. The ratio of 70 to 30 was found to be about the optimum for the use of shorts and still retain baking qualities of the flour. Samples of the blends were tested in several Middle Eastern countries and India-Pakistan under a Federation market development project during the period November 1966 to March 1967. The blends were found to be particularly adaptable for most Arab-type breads and also could be used for many local wheat foods such as roti and chapaties in India. Specifications are given in Tables 5 and 6.

Table 5.--Specifications - Blend A

Moisture	13.0% maximum
Protein, N X 5.7	13.5% minimum*
Ash	2.0% maximum*
Crude fiber	2.0% maximum*
Crude fat	1.8% minimum*
Lysine	0.5% minimum*
Bromate	100 ppm minimum 125 ppm maximum
Through U.S. Standard No. 20 sieve	97% minimum

*On a 14.0% moisture basis.

Table 6.--Specifications - Blend B

Moisture	13.0% maximum
Protein, N X 5.7	12.0% minimum*
Ash	2.0% maximum*
Crude fiber	3.5% maximum*
Crude fat	2.0% minimum*
Through U.S. Standard No. 20 sieve	97% minimum
Through U.S. Standard No. 100 sieve	65% minimum 80% maximum

* On a 14.0% moisture basis.

2. Precooked Protein Based Product. Extensive work was also carried on in developing a wheat based product that would meet the National Institutes of Health's nutritional guidelines (i.e., 20 percent minimum protein plus good amino acid balance and extra vitamin-mineral supplementation). In order to achieve the 20-percent protein level, soya flour was added to the wheat flour and wheat protein concentrate. The most satisfactory combination appeared to be 40.7 percent straight grade hard winter flour and 40.5 percent wheat concentrate with 16.4 percent soya flour plus 2.4 percent vitamin-mineral premix. This gave a food product of 81-percent wheat base which gives good palatability and maximum nutrition at a low cost. The protein efficiency ratio as reported by the Wisconsin Alumni Research Foundation was 2.06. The product in dry form had a raw taste and did not appear suitable for either beverage or gruel use without heating or cooking. After exploring a variety of types of equipment

that might be practical for heat treatment of this wheat based product, approximately 5 tons were processed under contract on a Wenger extrusion pilot plant near Kansas City. Three forms of extruded product were made, namely beadlets, flakes, and a semolina size granulation (ground beadlets). The palatability of the extruded product was found very satisfactory. The product could be used as a gruel or a beverage depending upon the granulation and amount of liquid used. The formula is given in Table 7 and the specifications in Table 8.

Table 7.--Wheat-based blend formula

	Percent
Straight-grade, hard winter flour	40.70
Wheat concentrate	40.50
Defatted soy flour, toasted	16.39
Calcium carbonate	1.00
Dicalcium phosphate dihydrate, USP	1.00
Sodium chloride, finely powdered	0.25
Sodium iron pyrophosphate	0.06
Vitamin and iodine premix	0.10
	100.00

Table 8.--Specifications - wheat-based blend

Moisture	5.9%
Ash	4.64%
Protein, N X 5.7	21.9%
N X 6.25	24.0%
Fat, ether extract	0.82%
Fiber	1.90%
Maltose	278 mg. per 10 g.
Calcium	1.60 g. per 100 g.
Phosphorus	0.46 g. per 100 g.
Iron	0.021 g. per 100 g.
Manganese	0.0060 g. per 100 g. (60 ppm)
Thiamin	1.075 mg. per 100 g.
Riboflavin	0.21 mg. per 100 g.

3. Bulgur Based Product (BA-Formula A). A gelatinized Bulgur based product designed primarily for beverage use for infants and small children was developed by the Bulgur Associates. The composition finally selected consisted of 70-percent Bulgur flour; 10-percent wheat protein concentrate; 18-percent toasted soya; 0.05-percent lysine, and 1.95-percent vitamins-minerals. The PER was 2.26 for this Bulgur product which has been satisfactorily used as a beverage base for infants and small children.

These basic products developed by the Federation's special committee have been evaluated by the Federal Committee on Food Processing for Developing

Countries, and as reported by Dr. Senti, procurement of them with some formula modification is planned.

It seems appropriate to close the discussion of MNF protein foods with a quotation from Dr. Betty Sullivan:

> The future is bright for a wheat-based beverage or protein concentrate. Our export of wheat products, however, will be determined by the Federal price support program. The certificate program currently requires the miller to pay 75 cents per bushel above the market price for donated products as well as domestic flour. Since the Federal agencies also must pay this additional cost, there may be preference given to competing products of lower nutritional value that are not subject to this tax and, hence cost less. Our current export subsidy system needs a thorough review if maximum advantage is to be obtained from wheat and its products.

I began this discussion with a warning that it is a "tale without an end." After describing the various interacting elements which provided the information and experience leading to formulation of a few specific wheat-based protein foods, I come to that part of a discussion which should normally constitute "the end." However, I prefer to think of this part of my talk as a new beginning, a beginning from which you and I will build on the past to generate new information and new products to eradicate hunger and malnutrition from the world of the future.

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DURUM IN THE RICE EATING COUNTRIES

M. H. Gifford
President, Great Plains Wheat, Inc.
Kansas City, Kansas

For those of you who have not had occasion to visit the Southeast Asian theater where rice is grown profusely, the title of my talk today, "Durum in the Rice Eating Countries," probably raises some exciting possibilities in your minds. I am sure that all of us in the North Dakota Wheat Commission when we first tackled the gigantic job of trying to find new markets for North Dakota hard red spring wheat and durum back in 1959 when the Commission was first formed, looked upon that area as a vast untapped market for pasta products. About a year ago, I had the opportunity of visiting this area as a representative of Great Plains Wheat, Inc. The wheat team, of which I was a part, visited all of the countries of this area in which market promotion work is carried on through Western Wheat Associates which is a regional wheat marketing development organization with whom we in Great Plains Wheat cooperate.

At the risk of becoming highly unpopular with my fellow North Dakotans, I think I would have to say that the market potential for durum in most of the countries which I visited is practically nil in the immediate future. There is one bright exception to this statement, and that is the country of Japan where the economy is booming. This I think, is the key that unlocks the vast market potential in the Asian theater for pasta products. We have to remember that durum is the Cadillac wheat of the world when it comes to pasta products. Consequently, as the economies of some of these countries improve, so will our opportunities for promoting the use of pasta products made from durum Semolina. To Americans like ourselves, it is very difficult to even imagine anyone not having enough money to buy enough macaroni or spaghetti to provide a meal for our family. I think therefore, so that you will have a little better understanding of the situation, I would like to review with you some of the things I witnessed while visiting some of these countries.

The first country we visited in this area was India. We arrived at the Bombay Airport about 5:00 o'clock in the morning, and as we drove in from the airport there were literally thousands of people sleeping alongside of the road and on sidewalks as we entered the city. The women were already busy preparing meals for their families. Almost everywhere you looked you could see women carrying vessels of water on their heads which I presume they were bringing home to their families in order to prepare their meals. The average Indian family has two meals a day, one in the morning and one in the evening. At the time I was there, each family was rationed on both wheat and rice. Each individual was permitted 6 ounces of wheat and 4 ounces of rice. Two or three months after I arrived home, I noticed by the paper that these rations had been reduced, first to a total supply of 8 ounces per person and then to a total supply of 6 ounces of both wheat and rice per person. This wheat and rice is purchased by them through the fair price food stores which are spread throughout the city. At the time I was there, there was widespread drouth in

the Northern provinces of India; and I was advised that the drouth was so bad in Bihar Province that some of the people were digging up the roots of grass and preparing a soup to nourish their families. The population in this country is staggering. There were some 430 million people in India at the time I was there, and they were predicting that by this time there would be 500 million people. In Bombay alone, the population was 10 million. The total area of India is less than the United States so that you can readily understand the density of their population. Even in the rural areas the population per square mile is tremendous. The average size farm is about 5 acres. The farmer that operates this land is invariably a sharecropper and will probably be supporting a family of 8 or 10 people. I could go on and on explaining what we would call at least dire poverty in our terminology, but I am sure most of you have either read or seen films on this subject. I am only calling it to your attention so that you will understand that the average Indian family consumes very little processed agricultural products. Any processing that is done is usually performed by the housewife as she prepares the meals. If she wants chapatties, she will first grind the raw wheat by hand and then prepare them. The rice of course is prepared much the same way we do except the rice is not polished as we know it, but is prepared in its raw form. The wealthier families, however, are able to purchase bread, cookies, and crackers from bakeries; but the number of mills and commercial bakeries are few and small. The imports to this nation are restricted by their Government to those items which they consider necessities. These do not include very many refinements. We did ship some durum to India under Public Law 480 the last 2 years, and it met the approval of the consumers of India because it more nearly resembled their local grown wheat. I would, therefore, expect that if India ever gets its economy off of dead center and move upward that the first purchase of durum would be for that purpose. The big potential, however, on the use of pasta products will be a very slow development which can only be brought about through an educational process of both eating habits and economic development. The Government of India has done much research on human nutrition and is fully aware of the nutritional advantages of wheat over rice. This coupled with the fact that the present food consumption of a large percentage of the nation's population is on subsistent levels could provide a tremendous new market for pasta products if their per capita income was ever raised substantially. About 80 percent of a family's income is presently used for food. Since the food intake is at bare subsistent levels in most cases, a huge portion of any increase in per capita income would go for increased food supplies. India, like most wheat importing countries where the importation is done by the Government, increases the resale price they charge the processors substantially to bring the price of the imported wheat up to that of the locally grown wheat. In countries where the wheat is purchased by the processors direct, a tariff is added by the government which accomplishes the same thing. These tariffs or resale prices, of course, tend to discourage the consumption of wheat and durum products because of the increased cost to the consumers.

In summary then of the country of India, even though the ultimate potential for pasta products is very great, it will take many years and a great improvement in their national economy before this potential can be realized.

Our next visit was at Bangkok, Thailand. The Thais are a very friendly nation, and their economy is improving rapidly, partially because of some of the activity that is taking place there because of the Vietnam War. The people of this nation have always been rice-eating population; but they, too, are discovering that they can sell 1 pound of rice and buy 2 pounds of wheat. The shift from the consumption of rice to the consumption of wheat products, however, has been slowed down because of the fact that the Government has placed an import duty on all imported wheat of 100 percent. The consumers of wheat products, therefore, do not derive the financial advantage they should from the consumption of wheat products. Even under these conditions, however, the consumption of wheat products has increased from 1.2 pounds per capita in 1962 to 2.8 pounds per capita in 1967.

At the present time, there are practically no pasta products consumed in Thailand; but as their economy continues to grow, I would expect them to start using it in gourmet dishes. It will take considerable time, education, and promotion before it is used in any volume.

Hong Kong might be considered the melting pot of the Southeast Asian area. You will see people of all nationalities and, of course, you still have the British influence there. There are, of course, many Chinese refugees in Hong Kong; and many of these prepare what they call Chinese noodles. These noodles are usually made from soft wheat and are shaped much the same as our long spaghetti except that it is larger. These Chinese noodles are whiter in color and when cooked are softer in texture.

Hong Kong is noted for its many small industries; and while it only consists of a 356-square mile area, they do have four flour mills. I believe that the secret of the introduction of pasta products to this area would be the installation of a small macaroni manufacturing company. This would not only stimulate the promotion of pasta products in Hong Kong, but since almost all industries in this area tend to export to other Asiatic countries, it could very well be a foot-in-the-door to the consumption of pasta products in other countries. They also have a sizable school lunch program in operation which gets some of its food supplies from the AID program here in the United States. If we could overcome the hurdle here in the United States which prohibits our furnishing manufactured products such as spaghetti and macaroni so that we could furnish macaroni and spaghetti through the Food AID program to these people, it would be a method of educating the pupils to eat this product. In introducing the new food product to an area such as this, it is somewhat like: What comes first--the chicken or the egg? Do you start with a pasta manufacturing plant and promote the product? Or do you promote the product and then get someone to put in a plant to supply the requirements? In summary, I would say that Hong Kong is an area where pasta product promotion could start paying off in a small way.

In the Philippines where Western Wheat Associates have been working for a number of years, the consumption of wheat products has risen only slightly the last 5 years. In 1962 they consumed 39 pounds of wheat per capita, and in the past year the per capita consumption was 40 pounds. The consumption

of U.S. wheat, however, is another story. Right after World War II when they were in the process of reconstruction, they recognized the fact they needed some industry to employ some of their people. In the course of a few years, they installed six flour mills. Since they were accustomed to buying their flour from the United States, they soon found that in order to sell the locally produced flour it had to be pretty much the same quality as they had been buying in the past. Western Wheat Associates provided a milling technician for the Philippines, and he was able to convince them that they should buy 15 protein hard red spring wheat from the United States to give them the type of product needed. One of these flour mills has now constructed a small pasta manufacturing plant. The production from this plant is mainly used for gourmet dishes for some of the wealthier people in the area. Unfortunately, they are not using durum Semolina to make the pasta products but are using Farina from the hard wheats which they import. As this market grows, I would expect them to start blending Semolina and Farina, and perhaps sometime in the future they can be persuaded to make some of their products out of pure Semolina. Some of the schools in the area have school lunch programs, and this is being expanded to other schools. Usually each school has their own bakery not only to supply the school lunch program with bread products, but it is also used to instruct some of the students how to prepare different bakery products. If pasta products could be introduced to the school lunch program, students could also be taught how to prepare them. To summarize the situation in the Philippines, I would say they are in the first stages of becoming consumers of pasta products. As their consumption increases, I would expect them to start with a blend of Semolina and Farina and hopefully eventually to some of their products manufactured from pure Semolina.

Taiwan, known to some of you as Formosa, is an island having a population of about 11.5 million people, 10 of which are Taiwanese and the balance Nationalist Chinese. These people are ruled by the Nationalist Chinese under the leadership of Chiang Kai-Shek. Their economy is improving very rapidly, partially because their agricultural economy is strong. In the past, they have been obtaining their wheat from the United States through Public Law 480, but this last year they were a cash buyer of wheat. They, too, have learned the advantage of exporting rice and importing wheat. The per capita consumption increased from about 39 pounds in 1962 to 59 pounds in 1967. Their economy also receives a considerable boost from the U.S. military bases there. Undoubtedly it would be of interest to you to know that the foreign currencies accumulated in that country from the wheat that was purchased by them under Public Law 480 have substantially all been used up by the military bases established there. I believe that the time is right to start promotion of pasta products in this country; and again, perhaps one of the easiest ways to get this started would be through one of the local flour mills in this country. In the city of Taipei, they have some very modern bakeries; and unlike some of the other areas I have visited, the bakeries were very well managed and were very sanitary. The eating habits of these people are becoming rapidly westernized, and their population appeared to be well fed.

In Okinawa, Western Wheat Associates have a very close working relationship with the baking industry and the one local flour mill. In the

marketing year of 1965-66, they purchased 96 percent of their wheat supplies from the United States. Western Wheat Associates have a mobile kitchen that travels throughout the island giving cooking demonstrations not only showing how to use wheat products but also showing the homemakers how to prepare western-style dishes that complement the use of wheat products. Many of these dishes consist of noodle-type foods. The people of Okinawa are mostly of Japanese descent and are a very ambitious people. Their economy is increasing rapidly; and here, too, I would expect to see the introduction of pasta products in the near future.

Japan is a very exciting country, not only from the standpoint of a tourist view, but very much so from a wheat producer's point of view when he is looking for new markets. The cooperation received by our Western Wheat Associates office in Japan through the Food Agency, the Milling industry, the baking industry, and the Japan noodle industry is beyond the realm of comprehension unless you can see it for yourself. The economy of Japan is improving by leaps and bounds, and there is a very notable shift from Japanese-type foods to western-type foods. The per capita consumption of wheat has increased from 54 pounds in 1962 to 97 pounds in 1967. This illustrates very dramatically the rapid shift to western-style foods as their economy improves. There is one of their eating habits, however, that I am not so sure that we should try to change, and that is the Japanese noodle. Wherever you go in Japan you can always find a little Japanese noodle restaurant where you can very reasonably buy a bowl of noodles. These noodles are served in a soup, and I can assure you it was quite an interesting experience for me to try to eat it with chopsticks. These noodles are manufactured much the same way as our macaroni and spaghetti except that they are made from the locally grown soft wheats in Japan. However, since they do not have sufficient supplies of locally grown wheats, they are supplementing these supplies with white wheat from the Pacific Northwest. Approximately 35 percent to 40 percent of all of the wheat consumed in Japan is consumed in the form of noodles. About 3 years ago, Japan started introducing pasta products to the market. They are presently using about 1/3 Semolina and 2/3 Farina in their pasta products. At first this market grew very rapidly, but has slowed down now to a more or less steady rise. As a result of the 1965 reduction in freight rates to the west coast, durum shipments to Japan increased from 48,000 bushels in the 1964-65 marketing year to 158,000 bushels the next year and 529,000 bushels in 1966-67. Spring wheat shipments were only 45,000 in 1964-65, but they increased to 6,435,000 bushels the following year and were 6,305,000 in 1966-67. Spring wheat and durum shipments in 1967-68 are expected to be double the amount shipped the previous year. These increased purchases are somewhat misleading, however, from the standpoint of pasta product consumption. Prior to the time the Japanese started buying U.S. durum they were buying some Canadian durum, and part of the increased purchases of U.S. durum was because of reductions in purchases of Canadian durum.

In summarizing the title of my talk, "Durum in the Rice Eating Countries," I think you would have to agree from some of the things I have told you that there are several factors which must be overcome in many of these countries before pasta products will be consumed in any volume. The first

and probably most important factor to be overcome in many of these nations will be an improvement in the national economies. The second factor in which we as a market promotion group will have to play an important part is one of food and nutritional education. The third factor is one in which our groups can have some influence, but in the final analysis must be accomplished by the food industry in these countries, and that is the introduction of pasta manufacturing plants. The fourth factor is a long-range one which would be the introduction of pasta products into the school lunch program setup in these countries, creating a taste for this type of product in the future generations.

I think you will have to agree with my original statement when I opened my address that while the immediate potential for the consumption of durum is rather small, when we look at it from a long-range standpoint of view, it can be a very exciting and challenging market.

THE NEW ERA OF GROWING COMPETITION CONFRONTING WHEAT FOODS

Howard Lampman
Executive Director, Millers National Federation Wheat Flour Institute, Chicago, Illinois

The subject of my talk today, "The New Era of Growing Competition Confronting Wheat Foods," sounds at first like an easy topic. But consider it a moment, and perhaps you will understand my struggle. I imagine the other speakers on your program all have patents--some exclusive bit of knowledge about some particular phase of wheat utilization. They can speak with authority. Then compare my subject. I am hardly an authority.

Everyone knows that the competition against wheat products has grown in the past and will continue to grow in the future. So what? It is like Mark Twain's remark about the weather.

Acknowledging this handicap, let us proceed to analyze the nature of our competition. Perhaps in the process we can find some kind of enlightenment. And please forgive me if I seem superficial, or perhaps too, too obvious.

When we mention competition, we presume the existence of a marketplace in which wheat producers, millers, bakers, pasta manufacturers, and others using wheat products, sell their foods. They compete with each other. They also compete with rival foods. And on the face of it, they or we, as the case may be, have not been doing too well. Not too many weeks ago, domestic consumption figures were again revised downward--to a new, alltime low level of 113 pounds per person per year. Macaroni products continue to prove the only bright exception in the steadily declining picture of consumption.

Or, look at the dismal picture another way. Using 1911 as a base year with per capita consumption of all foods at 100--cereal products have now lost 32 percent of their market. Potatoes fared worse--off 54 percent. Meats, fish, and poultry gained 27 percent; dairy products 5.6 percent; eggs 6.5 percent; and fruits and vegetables increased 30 percent in the same period.

We can explain this phenomenon somewhat glibly by pointing out that in an affluent society, such as ours, people eat more meat and less bread. But that is not too satisfactory. We can say that bread, the principal product of wheat, has not changed much in the past 6,000 years, and that pasta was supposedly introduced to Europe by Marco Polo in the 13th century. So our products are time-honored foods, but there is small comfort in mere age when the world keeps demanding foods that are new. We live in a new world and compete in a new kind of market. Let us examine it.

People buy food for a variety of reasons--taste; convenience; availability; cultural or family tradition and personal habit; nutritional benefits and economy. If we use these reasons for purchase as a scale, we can rack up a high score for the products of wheat--perhaps a better total score than for any other group of food products.

Bread obviously has taste appeal, whether you prefer the bland flavor of the standard loaf or the wheatier specialty breads. Even the blandness of the standard loaf has advantages since it permits you to taste the stronger flavor of spreads and fillings. And, if you do not like the standard loaf, you can always buy a specialty bread.

Bread represents something of an ultimate in convenience, since you can eat it without heating, presliced, directly from its package.

Bread is readily available, perhaps more widely distributed in a multitude of forms than any other food.

Bread is a deeply imbedded part of our food habit patterns. It is highly nutritious and relatively low in cost. In addition to these attributes, bread is a go-together food supplementing many other items in preferred diet. In fact, properly presented, it might be said that no other food can match the appeal of breadstuffs.

Now, if bread has all these advantages, what are the competitive forces that appear to be slowly pushing us out of the marketplace and off the family table? To me, the answer seems quite obvious. The human stomach holds from 2 to 5 pints of bulk. If wheat foods gain, other foods lose. If other foods gain, wheat foods lose. The difference, it seems to me, lies in the strength and effectiveness of the marketing effort.

To bring some order to the situation in my own mind, I have somewhat arbitrarily catalogued the competitive factors as a series of "battles." The analogy may be apropos, since if we are to keep or maintain our place in the market, we must engage in an all-out, full-scale, competitive war and prepare for a constant battle on all fronts. It is no longer possible to invent a better mousetrap and have the world beat a path to your door. The world does not care unless we make it care--and that step demands that we muster all the forces of modern marketing. Some of these forces are exerted on domestic sales, some worldwide.

Our first engagement is our battle with rival products--foods that might be substituted or exchanged for breads and other wheat products in the standard meal pattern, foods like rice, potatoes, and corn--all perhaps more aggressively promoted than wheat products in many situations. I have heard a miller complain, for example, that the corn industry's foundation

had persuaded two of his better customers that the substitution of some corn flour not only was cheaper than wheat flour but actually enhanced the taste.

On the export side, most of you attending this conference know more than I about CSM-Mix, Ceplapro, and similar formulas of wheat, corn, soy, and other ingredients blended as high-protein foods. Mention should also be made of fish protein concentrate as an additive to increase the protein value of bread at the sacrifice of some wheat flour. Or, bread made entirely without wheat flour, or bread that carries added proteins derived from petroleum.

Such products exist. They have been exhibited, publicized, and ofttimes vigorously promoted as the answer to world food problems and protein needs.

In this day of technology, we find "milk" without cows, sugarless sweeteners, meatless hamburger. There is both a threat and a promise in such new developments. We may yet find wheatless bread on the market one day. But there is also a lesson in the experience of the potato industry, which is enjoying an upward surge in the sale and consumption of instant forms. Technology can help as well as hurt us.

But I am more interested in the proportion of wheat found in the 2-1/2 tons of food eaten each year by the average family of four in the United States. Which brings me to another battle of the marketplace--the conflict of choice.

In the past 30 years, the number of items in the supermarket has increased from about 800 to as many as 8,000. Bread and other products of wheat obviously gained more prominence among 800 items than among 8,000. And the majority of those 8,000 items are new and exciting while bread is taken for granted. The competing products clamor for attention, purchase, and use in their prepackaged, preproportioned, premixed, convenient, easy-to-use, colorfully packaged form. In the past 30 years, the sale of convenience or partially processed foods has risen from 50 to 70 percent of total store volume. While a loaf of baker's bread may be an ultimate in convenience, the impact of the trend on family flour is obvious.

As everyone is well aware, convenience foods cost more--and this brings us to another battle front. A decreasing proportion of the consumer dollar--now about 20 cents--is spent on food, and farmers, processors and bread manufacturers, and retailers as well, are caught in a cost-price squeeze. In an effort to solve some of the problems of increasing labor cost, the baker turned to the technologists who developed highly automated machinery--like continuous mixing equipment. Then, in an effort to save some of that money

for himself, the retailer bought the same equipment, so that he could offer the same bread under his own label at less price--without the burden of advertising and promotion. Or, sometimes the retailer contracts with a baker for bread production, and in effect sells the same bread in two different wrappers under different names.

At this time, almost half of all baked goods offered by chains sell under a private label, often as a "loss leader." You might say that this immense volume of bread, sold without advertising, tends to depreciate the total market since it rides on the promotion of advertised brands without carrying its fair share of the cost of merchandising pressure necessary to sell a food in today's market.

There are several aspects of the race toward mechanization that also work to the competitive disadvantage of wheat foods. The distribution costs of the commercial baker continue along with his advertising, whereas the chain baker simply uses his own trucks to deliver his bread. Because the trucks are going to the retail outlets anyway, there is no charge for delivery or the pickup of "stales" added to the cost of the private label bread.

Thus the battle of distribution, serving the nation's almost 250,000 food stores, which sell more than four-fifths of all flour in one form or another, has become all important in the competitive battle. Forty-seven percent of sales are made through chain stores; 44 percent through cooperative and voluntary chains, leaving the small balance to the corner grocery traditionally run by "mom" and "pop." The stress of distribution costs in the competitive situation actually limits the promotion of baked foods, since the wholesale baker must meet the price level set by chain store bread at the sacrifice of what might otherwise be spent for marketing.

Another facet of mechanization of the milling and baking industries has been the standardization of bread and flour--consequently robbing both baker and miller of the most essential ingredient of marketing success--the claim to real or attributed product advantages. How can one brand of bread or flour be better than another if they look, taste, and perform exactly alike? The only competition possible under these circumstances becomes one of price--with disasterous results.

Another constant battle of any food product is competition for shelf space and position. Food retailers have become increasingly sophisticated in their approach to the allotment of space and position. They know that products displayed more prominently, at eye level, with larger areas of facings, sell in high volume. Naturally they tend to give their own private labels the advantage. They compute the value of such position in terms of "shelf rental." Even though the occasionally publicized fact that family flour helps sell other items used for home baking with consequent higher sales at the check-out

counter, the shelf space devoted to family flour appears to be shrinking. After successful demonstration that a sandwich promotion increased sales storewide by 15 percent or more, part of the record of Sandwich Month, there is evidence that space devoted to bread has increased.

There are many other considerations in today's system of marketing foods which bear on the struggle to sell those derived from wheat. One area might be called the battle of calories. Influenced by an almost constant campaign citing the hazards of overweight, an increasingly large proportion of our population worries about obesity, tries crash diets, buys low-calorie foods, and attempts to manipulate weight. Unfortunately, largely because of nutritional ignorance, these people believe bread to be somehow peculiarly fattening. The result not only reduces the consumption of bread but also stigmatizes a worthy food product.

Nutrition is in itself a battle area--domestically where some baked foods are promoted on the basis of being nutritionally improved, and in foreign aid programs where the hue and cry is "protein." The fact remains that, if a product seems to require nutritional improvement, then logically it must be deficient to start with in some way. Such a conclusion is almost inescapable, and in some ways "nutritionally improved" foods tend only to depreciate those similar products not "improved."

It is difficult, indeed, to merchandise a high protein loaf of bread or wheat product without suggesting that all other breads and similar products are low in protein. In this fashion some of the technology that permits product improvement tends to depress the total sale of all wheat foods. And if all products of wheat are so improved, as with enriched bread and flour, then enrichment becomes standard, unexciting and works to no ones particular advantage. Yet the public health benefits of enrichment are almost incalculable.

This is not to suggest that that effort toward product improvement be abandoned. Rather it should be intensified and applied to wheat products in such a way that it provides them with competitive advantages over nonwheat foods rather than against their own kind of foods.

This brings us to the battle of new product forms and product improvements, either in packaging or substance. The development of bulgur serves as a good example of what can be done to open vast new market areas. Or, the profusion of new wheat-based snack foods suggests that the trend is just beginning. Yet we should not rest easily in the mistaken notion that the same technology is not being applied to competitive foods. If anything, the wheat-oriented industries appear to be laggard in the race to find new outlets.

GPO 808-415-6

Competition among foods shows up no more dramatically than in advertising. The magazine, "Advertising Age," reported in August 1967 that 125 top advertisers invested almost $4-1/2 billion in all media in 1966--a 12 percent increase over 1965. But only one of those 125 top advertisers was a baking company. Continental, ranked 85th with a $17 million expenditure. Three milling companies were listed--General Mills ranked 22nd, with $54 million; Pillsbury 45th with $30 million; and Quaker Oats 53rd with $26 million. National Biscuit Company was 33rd, spending $43 million.

That may sound as though huge sums of money are being spent in behalf of wheaten foods in competition with other products offered in the supermarket. But there is what might be called a "joker" in the hand. Most of the advertising money spent by mills is devoted to the marketing of snack foods, breakfast cereals, mixes, and other products, many of which have little or no wheat in them. Advertisers tend to put their money where their greatest profit lies. And think of the competition for consumer minds and money represented by the $4-1/2 billion spent for advertising.

Retailers, however, tend to feature and merchandise those products which are advertised, and advertising volume in itself may be used as an index to the success of an industry or a company. On this basis one can only conclude that the products of wheat stand in dire need of advertising. It can be demonstrated that even a small investment in advertising pays off in greater sales, even for commodity foods featured without brand names.

There is another battle area in the competitive struggle--an area more akin to psychological warfare. It is the battle for product prestige, stature, or "image." One would think that any food called, "the staff of life," and named in the Lord's Prayer carried distinct advantages in competition with other foods. But the sale of flour is highest among low income groups and the curve of consumption declines as income rises. Bread consumption climbs until family income reaches the $10,000 a year level, then drops sharply. Another survey indicated that among adults bread was considered a "filler-upper," something good for children but of dubious value for grownups.

Baking company advertising reflects the situation since it is beamed primarily at the child market. Obviously one of the greatest problems we face is trying to make bread somehow as important as it was when it was named in the Lord's Prayer. Or, failing that, we must find some way of making it more important as a food that contributes to personal health, national welfare, and the pleasure of eating.

Finally, a vignette of this rapidly changing market where foods compete for consumer favor. You have heard the often quoted statistic that half our present population is 25 years or younger. There are 63 million boys and girls under 14 years of age to whom one baker says he sells 2 million pounds of product every day. The under-30 population group soon will dominate, if it does not already, our national life. Our marketing plans and methods of

winning consumer favor competitively must be directed to the young, who do not conform to what we consider standards of today, either in thought or action. Pepsi Cola, you may have noticed, and many other advertisers are making a studied attempt to reach this younger generation.

How do you reach them with a product essentially as old as bread? Well, one way is to make macaroni, flour, or bread into a product that is entirely new, because this market constantly seeks the "new." New sandwiches and recipes for new dishes are an example. There are many ways of reaching the market, and many manufacturers of precooked and prepackaged foods are succeeding in showing us how--in the form of processed potatoes, oven-ready pizzas, cake mixes, brown and serve rolls, and convenience foods.

And the market is about as static as a drop of water on a hot stove lid. Experts predict it will change as much in the next few years as in the preceding 50--which, you must admit marked a revolution insofar as food marketing is concerned. The big question, to me at least, and hopefully--to the others attending this conference--will we be able to adapt our thinking and our products to the new market? We have the tools, I know--but will we be able to use them? Our competition is going to intensify rather than slacken. We must win all the competitive battles, every one of them, if we are to win the war.

NEW MILLED CORN PRODUCTS INCLUDING CSM

Bert Tollefson, Jr.
Executive Director, American Corn Millers Federation
and Export Institute, Washington, D.C.

It is always a special pleasure to come home to Dakota. Watertown, South Dakota, is hometown for my wife and me. Many of our relatives live here in North Dakota, most of whom farm in the western part of the State. Many of our other relatives farm in eastern South Dakota, so substantial amounts of corn and wheat are produced in these operations.

Corn, wheat, and other grains from America's agricultural heartland are making great contributions in the most vital struggle against world hunger and the directly related geopolitical competition for men's minds and nation's allegiances. Food from American farms and factories is being used appropriately throughout the world in the most extensive undertaking in history to alleviate hunger and malnutrition. Since Public Law 480 was passed by Congress in 1954, the Food for Peace program initiated in the 1950's evolving into the current War on Hunger, the humanitarian sharing of nature's abundance, has been a remarkable achievement. But food has also become our most effective instrument of foreign policy. It is in this vital context that we convene at this conference.

The American Corn Millers Federation and Export Institute has 75 member companies in 25 states, and our companies and the Federation are involved in various projects with other companies represented here today who are not corn millers. Several of you here today represent companies which are good customers of the corn milling industry; we appreciate that vital relationship and only hope that it might be expanded.

Also in the audience are several longtime friends from government, a number of whom have made vital contributions in the development of new cereal products, including new milled corn products. Our industry appreciates those efforts.

All of us in the room are directly involved with the vital problems caused by increasing world population and the almost proportionate increase in world food needs as food supplies fail to keep pace despite improved production through research and technology. We are all familiar with the statistics and the projections of food need varying from severe malnutrition in some areas to even possible famine in certain areas if solutions are not found. Leading nutritionists, including Dr. Fred Senti, who spoke here, state that supplies of both protein and calories are near or below the minimum needed for adequate nutrition for much of the population in developing nations which composes two-thirds of the world's population. The Food and Agriculture Organization of the United Nations headquartering in Rome, recommends 60 grams of protein as the minimum daily adult allowance. The average protein supply

per person for the developing nations, comprising two-thirds of the world population, is about 57 grams per day, contrasted with the average protein supply per person for the other well fed one-third of the world population, estimated at 86 grams. Some of the hunger and malnutrition problem is, of course, caused by poor distribution of available supplies. In the underdeveloped countries, some have higher and others lower supplies of available protein. The supply of protein also varies within a country by region and by population groups.

Through the years, the American corn milling industry has made a substantial contribution towards alleviating world hunger. Frank Ellis spoke here yesterday in his capacity as Director of the Food for Peace Division in the Agency for International Development. About 1 year ago Frank stated that during the past 12 years 3-1/2 billion pounds of corn meal had been distributed worldwide through the United States Government and private agencies, creating 9 million years of life food energy. In addition, our companies in the Federation are involved in other food marketing programs that continue to alleviate world nutrition problems while expanding commerce. Both elements are essential to world peace and continue to receive top priority by our Federation and Export Institute.

During the month of November 1957, I was a member of the United States Delegation to the Food and Agriculture Organization Annual Conference in Rome, and recall the many conversations, particularly with delegates from underdeveloped nations, on the most vital challenge of providing adequate diets for the world's population. Out of meetings such as this evolved the concept of Food for Peace, which was established in 1959 as an amplification of Public Law 480 which had been functioning since 1954. As world population has spiraled upward, all political, economic, and social problems are understandably intensified in areas where food supplies are short.

The world is now at the point where no problem is greater than food supplies and population trends. The concept of Food for Peace, War on Hunger, and all related commercial endeavors must have top priority and require the best ideas of everyone assembled at this Conference.

The challenge of providing adequate nutrition then is based first of all on humanitarian response and geopolitical needs, but there is also great opportunity for innovation in research to develop new foods that will meet world food requirements.

In June 1966, several Congressmen during a colloquy in the House of Representatives, discussed additional contributions that could be made by corn milled products in world food programs. Included in the Congressional Record is a summary description of four of our industry products which might serve as a background for our further consideration on the subject. The text reads as follows:

DEGERMED CORN MEAL (ENRICHED)

During the past decade, U.S. food aid programs have brought over 140 million tons of food to hungry people. Degermed corn meal, a basic product of the American dry corn miller, has always been a vital part of this program. It is expected to play an increasingly important role in Food For Freedom scheduling as world demands on total U.S. cereal production require a greater call on American corn.

Enriched corn meal is both economical and nutritious and lends itself to use in hot breads, main dishes, and desserts. Extra food values contained in vitamins are added to corn's important natural iron, calcium, and protein in this product.

PROCESSED CORN MEAL (ENRICHED)

For hungry millions of all ages who have no ovens and only the barest minimum of fuel, processed (precooked) corn meal fills vital needs which cannot be met by any other cereal. Its unique characteristic is that when mixed with water it forms a corn dough and is thus ideally suited for those large corn-oriented areas, particularly in Latin America, where grain production has been outstripped by exploding populations.

Of equal importance, processed corn meal is the only cereal acceptable for the widely popular and nutritious corn beverages which are a staple food throughout Latin America where they are known as atol, pinolillo, chicheme, colada, and chicha dulce.

In many areas where the traditional food is of the tortilla or empanada type, processed corn meal was found to fill a basic requirement rooted in the medically proven axiom that "the closer people are to starvation, the more difficult it is to change their food habits."

While industry has for years manufactured products similar to processed corn meal for use in the food and beverage industries, it was not until 1963 that intensive industry-financed acceptability tests of processed corn meal were conducted in more than 30 countries around the world, including 10 in Latin America, with uniformly excellent results.

The American Council of Voluntary Agencies, which represents all voluntary agencies engaged in overseas feeding, has asked for processed corn meal under worldwide U.S. donation programs because it fills urgent needs which cannot be met by any other cereal.

CSM

Deriving its name from the initials of corn, soy, and milk, CSM is a new food for infants and children, formulated by the United States Department of Agriculture's Agricultural Research Service. It contains a well balanced assortment of necessary nutrients and approaches the optimum desirable cereal-protein ratio. It is specifically designed for infants and children in low-protein status who require prolonged feeding to achieve normal levels of metabolism.

CSM's basic cereal component is processed (precooked) corn meal with added defatted toasted soy flour, nonfat dry milk, calcium carbonate, and a vitamin-mineral premix. The result is a 20 percent protein food with an adjusted protein efficiency ratio of 2.42 to 2.48 and a nutritionally approved amino acid balance. It is virtually bran-free and has a bland flavor and smooth texture. Produced in powder form, it is precooked and ready for infant or child feeding after 1-minute boiling. It is fed as a gruel, as a beverage, or in other forms.

CSM has been tested successfully for acceptability in Southeast Asia and Latin America, and industry is prepared to fill immediate mass needs worldwide.

CEPLAPRO

Ceplapro is a high-protein, enriched corn-based food in kernel form resulting from the ingenuity of corn millers and outstanding nutritionists and providing the answer to specific requirements of President Johnson's new Food For Freedom program.

Ceplapro is of particular interest to areas where rice is a staple in short supply. It is adaptable to the many meat and fish dishes peculiar to Southeast Asian and Latin American eating habits.

It meets rigid specifications to provide an answer not only to hunger, but also to malnutrition, particularly among the world's preschool children whose nutritional requirements are the special concern of the new program.

One hundred thirteen grams per day of Ceplapro will provide one-quarter of a preschool child's energy needs and approximately half of all of his other nutritional requirements.

Ceplapro is composed of degermed corn meal, durum flour, defatted toasted soy flour, nonfat dry milk, calcium carbonate, and a vitamin-mineral premix.

Ceplapro's protein content ranges from 18 percent to 20 percent by U.S. Government specification. Its adjusted protein efficiency ratio is in excess of 2.25.

Of these products, Degermed and Enriched Golden Corn Meal continues to be our major product, as it is used in many forms throughout the world. The ingenuity of the American farmer has produced abundant supplies of corn. The history of our nation's growth is linked with the many uses of corn beginning with the first Colonists to set foot in the New World at Jamestown and Plymouth Rock.

Milled corn products are now used for a variety of food and industrial purposes. Corn has aptly been described as the "grain that built a Hemisphere."

When Soviet Premier Khrushchev visited the United States in the fall of 1959, the first place he wanted to visit was the United States Department of Agriculture's Experiment Station at Beltsville, Maryland. I was in the group of five that hosted the Premier and his party and recall how vitally interested he was in corn production as evidenced by his comments and later statements while visiting corn farms in the Midwest. Khrushchev knew from his experience as a farm boy in the Ukraine that increased corn production in the Soviet Union was essential to their objectives of improving nutrition, increasing livestock and dairy production as well as industrial applications. The climate and soil, along with other factors, have not been conducive to corn production in the Soviet Union, and Premier Khrushchev and his successors have been unable to make good on their statement that they would overtake us in agricultural production.

Because corn products are basic to the diets of so many nations in the world, our production capacity and ingenuity give us much greater responsibilities and opportunities in combating hunger and malnutrition.

CSM has been developed at a time when there is increasing need for high protein, low cost foods. Since September of 1966, CSM has been distributed to over 100 countries with very good acceptance. Food tests have proven its nutritional value. CSM has been fed to children and mothers and the response has been enthusiastic. The United States Government has purchased 332 million pounds of CSM. In addition to the government purchases, UNICEF has purchased 7 million pounds of CSM and is considering more distributions to needy children based on favorable responses.

Nutrition specialists say that incidence of protein-calorie deficiency is greatest among children in the weaning and immediate post-weaning periods when, deprived of breast milk, the child is not yet old enough to fend for himself. The protein requirement per unit body weight for these children is approximately twice that of adults. Pregnant and lactating mothers compose another group in whom the effect of low intakes of protein may have harmful effects on the children.

This situation contrasts with that of most other adults where critical shortages of protein rarely exist except where accompanied by a shortage of calories. Eventually, as CSM is distributed in greater amounts, or is produced in countries from local available commodities, adults will consume CSM in substantial amounts because of its palatability and practicality. CSM can be prepared as a porridge, gruel, soup, hot drink, or formed into a dough for use in such foods as tortillas, empanadas, chapatis, and enchilladas.

Two weeks ago, more than 40 Senators attended a Corn Meal Products Luncheon in the Capitol Restaurant and expressed enthusiastic approval of the various corn meal foods, including corn bread, spoon bread, corn grits, CSM soup, Indian hush puppies, and even a cornflake dessert. This provided an opportunity for key government officials to sample some of the foods being distributed throughout the world to hungry people. Several weeks ago we had a similar luncheon with 60 House members. While corn bread is served every day in the United States Capitol Restaurant and is very popular, one of the Congressmen at the luncheon enjoyed the CSM soup so much he had 3 cups, and limited his lunch to that.

A recent issue of UNICEF News refers to CSM as "the first attempt in history to introduce a new food product simultaneously to millions of people on a worldwide basis." UNICEF officials believe it will work. Experience has proven it has worked.

The British nutrition expert N. W. Pirie, writing in the February 1967 issue of Scientific American, stated that eating habits can and will be changed with the hungriest peoples being helped the most with new high-protein processed foods.

The President in the State of the Union Message emphasized the vital importance of developing programs and policies to meet world population growth and resultant food needs. This concern has been reaffirmed by Congressional leaders of both parties and officials of business, labor, government, and voluntary agencies.

The noted historian Arnold Toynbee, in discussing his challenge and response theory of history, cites civilizations such as the Babylonian and Roman Empires that failed to adequately respond to challenges, began to deteriorate and eventually disappeared. One of the greatest challenges facing the United States in our position of leadership is the world food and population

situation. The corn milling industry is committed to provide manpower, research, and production capacity in participating with others to assure that our national response is sufficient for the challenge.

Our industry accepts our portion of the responsibility but we also consider all the circumstances to provide special opportunities for the potential productivity of American farmers and creativeness of American industry. We also recognize the essentiality of our nation assisting underdeveloped countries to develop expanded agricultural production and processing capacity. Our member companies have established plants and marketing operations throughout the world and are working on additional new projects in this area.

In this room are many persons from government and industry who have made valued contributions in nutrition research and cereal science. Our Nation's response to the startling challenge of world hunger and malnutrition will prove to be effective and sufficient but it will require courageous leadership, difficult decisions, and imaginative research.

Each of us has a vital role to play as part of the total effort that will comprise our successful national response.

Food and protein will determine the destinies of all civilizations and all mankind.

SECOND GENERATION PROTEIN-FORTIFIED WHEAT AND BARLEY PRODUCTS FOR EXPORT

James W. Pence
Chief, Cereals Laboratory
Western Regional Research Laboratory
Agricultural Research Service, U.S. Department of Agriculture
Albany, California

Up until a short time ago, all of the food products which entered the export market through concessional sales or donations were individual products. By that I mean that they were single items, such as wheat, flour, bulgur, or dry milk. With the coming of Blended Food Products, however, we could say that we have started what might be referred to as a second generation of food products--derived products, if you will. Examples of this second generation were discussed by Dr. Fred Senti and Dr. Bill Johnston. These represent the first round of new products based on the wheat protein concentrate. There are some other products of a second round or second generation of new wheat products that have been conceived and are under development at our Laboratory and elsewhere. Today, I should like to tell you of some of these yet unborn products. We are hopeful that they may make their entry into the export food scene in a normal course of time.

You have just heard about "New Milled Corn Products Including CSM" from Mr. Tollefson. CSM represents a low-cost highly nutritious and palatable food product, of that there is no question. However, we feel that the outlook is also excellent for similar products made using other cereals as the basic ingredient. We envision equally low-cost and just as nutritious and palatable products made with wheat or barley, perhaps to be known as "WSM" and "BSM" if you like. These products should be equally as good in all respects.

An obvious and primary consideration in such products is the cost of producing them. They will have to be as inexpensive as possible, and the cost of materials from regular milling and malting often is just too high. We have therefore, been looking for new ways or simplified ways of producing the necessary wheat or barley ingredients for such new blended food products.

Our major early concern, therefore, has been to produce ingredients which meet nutritional and esthetic requirements at as low a cost as possible. Furthermore, it was desired to base the processing insofar as possible on modifications of the bulgur, malting, or regular milling processes, so that the ready and available production capacities of these industries could be utilized.

First off, we thought that a product in a granular form similar to farina would be desirable because, when cooked, it would have a more pleasant texture than one of finer grind, such as would be obtained with regular flour. Of course, we could not consider using farina itself because its yield in normal flour milling is too low to be practical. We have, therefore, attempted to achieve a product with similar granularity by processing the whole grain

and by coarse grinding. Alternatively, we have also considered rolling of the processed grain, with or without subsequent coarse grinding.

With all of the above conditions in mind, we have concentrated on a simple type of process in which the moisture content of wheat or barley is adjusted, within certain limits, and the damp grain then processed by steaming. It is finally dried directly, or perhaps rolled and dried.

If the kernels of these grains are to be ground almost entirely into a granular state similar to that of farina, some method of first removing the fibrous, colored, and otherwise undesirable bran tissues is necessary. With barley, this could easily be accomplished by pearling it prior to the wetting and steaming. This was not so successful with wheat, however, because the wheat becomes sticky and hard to handle. Therefore, the bran is removed after the steaming and drying. As you recognize, this is a relatively small variation of the regular bulgur process. It is less expensive, however, because the moisture uptake, the cooking, and the necessary final drying are all used to a lesser degree.

We found that satisfactory dehulling of barley and debranning of wheat can quite readily be accomplished in a small carborundum-cone abrasive rice mill which is available to us. Other abrasive mills currently used by bulgur processors and barley processors would undoubtedly perform as well.

Reducing the crude fiber content to about 1 percent by this means seems to be a reasonable compromise among yield, fiber content, and the ability of the grain to perform satisfactorily in subsequent processing. To achieve a fiber content of 1 percent requires about a 20 percent weight reduction for barley and some 8 to 10 percent for wheat.

We are continuing to study the effect of moisture level and steaming time on product characteristics for dried and for rolled-and-dried products. The moisture range of interest has been about 15 to 40 percent. Steaming time has been varied from 10 to 30 minutes. Any combination used so far has been capable of producing partially cooked grain that can be ground into a coarse meal or can be rolled satisfactorily when fed at 140°-160° F. to cold rolls. Figures 1 and 2 will give you a general idea of how the grains and the products look before and after the processing.

Some general observations based on our incompleted studies are possible and will be of interest. As moisture content at time of processing is increased upward from 15 percent, the appearance of the product, especially the rolled product, changes from an opaque dull gray or brown to a nearly translucent golden brown at 40 percent moisture content. Similar but less apparent color differences exist in the unrolled product. When ground, of course, the products become much whiter and mealy in appearance. The barley flakes are quite a nice looking and tasting product.

An evaluation of flavor was conducted on samples of the ground products introduced into boiling water and simmered 2 minutes, as is called for in the guidelines for this type of product. Twenty minutes steaming at 20 percent

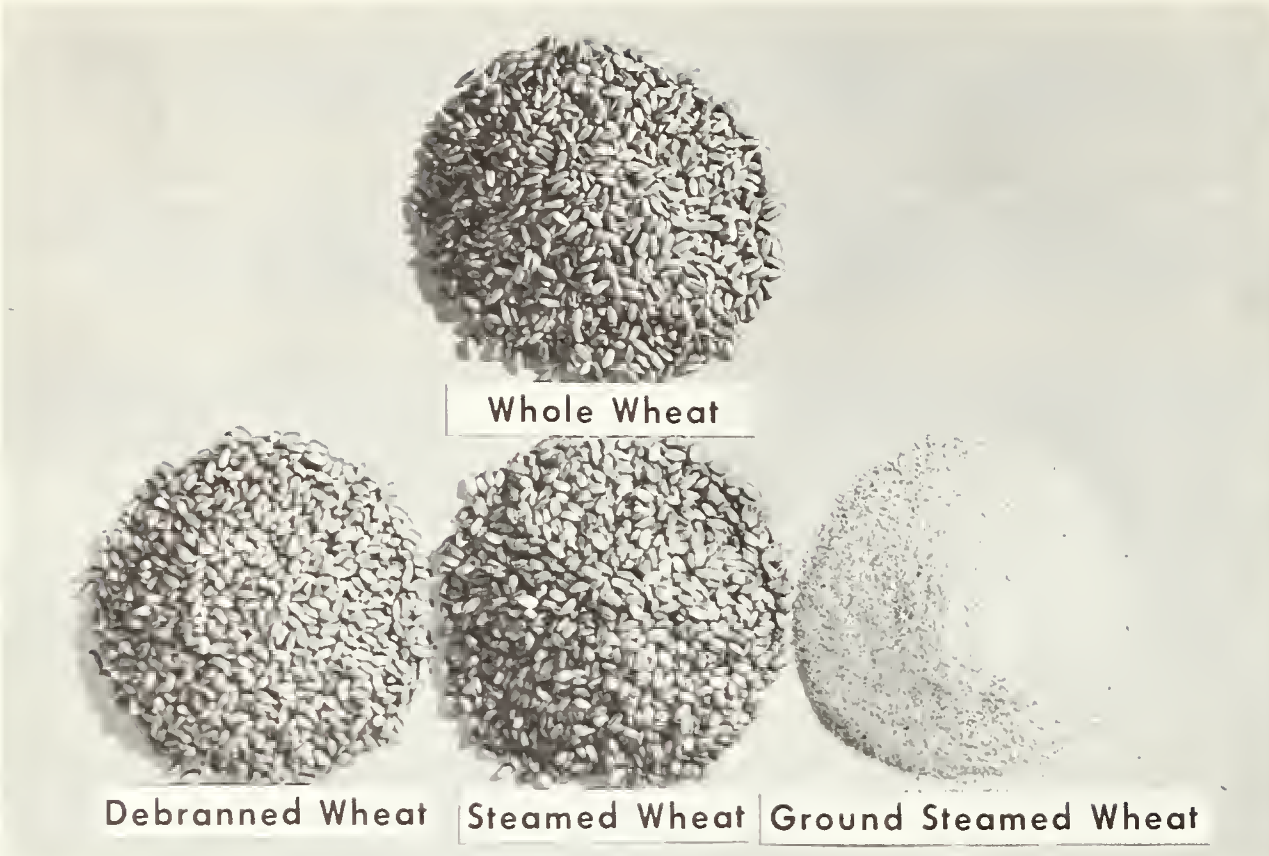

Figure 1. Hard red winter wheat debranned by mechanical abrasion; moistened and steamed; and ground after drying into a coarse, farinalike meal.

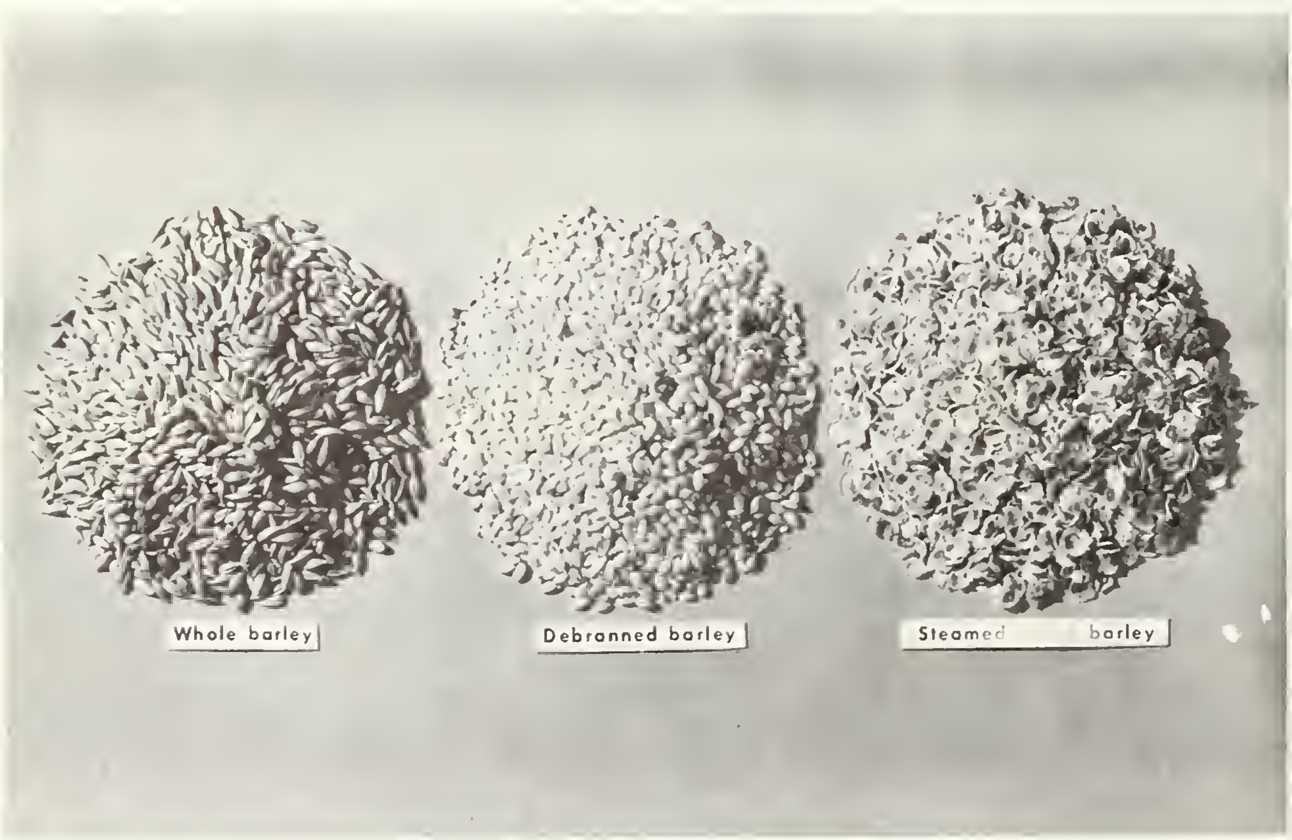

Figure 2. Barley dehulled and debranned by mechanical abrasion; moistened and steamed; rolled into flakes, and dried.

moisture, for example, was sufficient to remove the raw grain taste. Longer steaming gave a better flavor, but so does the cooking when the final product is prepared for serving.

Grinding of the steamed and dried grains can be accomplished in several ways. We found hammer mills to tend to produce a large proportion of fines. Burr mills seem to provide both a good control over a wide range of particle size possibilities and an ability to concentrate the particle size into a fairly narrow range, without any sifting or classification.

When the processed whole grain is ground properly, a soft but still distinctly particulate texture is obtained in the cooked final product. The rolled flake form when ground, gives a cooked product of smoother texture, but it is not pasty.

In the purchase specification for CSM there are requirements for hot and cold consistency measurements of the final product in a Bostwick consistometer. The purpose of these is to estimate and control the amount of cooking given to the corn ingredient. Particle size in the blend will also affect the consistency values somewhat.

For our products, also, the effect of particle size distribution superimposes upon the effect of processing conditions, both affecting the final product consistency. Since the Bostwick consistencies (hot and cold) are intended to indicate the proper degree of heat processing, they do not seem to be quite as directly applicable to the proposed wheat and barley products because of the large effect on particle size distribution of the grinding after steaming and drying.

We are currently investigating less empirical methods, or at least some other method, for assessing degree of processing. Soluble starch was explored, but differences over the full range of processing conditions were only about 3 percent. This range is too narrow for significant differentiation among samples processed to different degrees. The Brabender viscoamylograph is currently being investigated. Other possible methods will also be explored.

Perhaps a test for lipoxidase inactivation can be used to reflect adequate heat treatment, and a hot consistency measurement to specify the desired eating quality at point of use. In this connection we have found that the test for peroxidase inactivation to control vegetable blanching in the frozen food industry can be successfully applied to steamed moist grains.

Many of you are aware that proposed Blended Food Products must meet stated guidelines for composition and nutrient content. Set forward in these guidelines are requirements for energy, protein, essential amino acids, fat, fiber, minerals, and vitamins. Table 1 shows how a wheat or barley-based product complies with these guidelines.

Table 1.--Guideline requirements and quantities of nutrients supplied by prepared wheat and barley blended food products (grams/100 grams)

Constituent	Guideline Minimum	Guideline Maximum	Barley	Wheat
Protein (N X 6.25)	18	22	21.5	21.5
Essential amino acids				
Lysine	0.95		1.08	1.06
Total sulfur-containing	0.60		0.65	0.67
Methionine	0.30		0.33	0.32
Cystine			0.32	0.32
Tryptophane	0.22		0.29	0.29
Threonine	0.65		0.79	0.79
Crude fiber	0.50	1.0	1.49	1.41

The formula used for the calculations was 68 percent cereal ingredient, either wheat or barley; 25 percent soy flour; and 5 percent nonfat dry milk. Only the values for protein, essential amino acids, and fiber are shown in the table. Fat, minerals, and vitamin shortages are allowed to be made up through additions to the formula, so these are not shown.

The guidelines are readily met in all regards except crude fiber. These products should, therefore, be satisfactory, if a content of under 1.5 percent crude fiber can be tolerated and maintained as indicated here.

To turn to another type of new food product, we have all heard about Blended Food Product - Formula No. 2, which is the Sunday name for CSM, but you may wonder whatever happened to Formula No. 1. This is the Ceplapro that Mr. Tollefson just described. This too was a CSM-like product but extruded in macaroni equipment to a grainlike shape, about 1/4 inch long and 1/16 inch in diameter. It contained about 10 percent durum flour but otherwise was similar to CSM in formulation, if not appearance.

Some work has been started at our Laboratory and elsewhere to produce a similar grainlike product using wheat protein concentrate as the basic ingredient. The grainlike form is produced by extrusion of a dough through a macaroni press using a special die such as is shown in Figure 3.

The openings in the die are lens-shaped. The flow of dough through the openings is greatest in the wider center region and diminishes toward the extreme of the openings, thereby producing the desired grainlike form. The cutter rotates on the die face, and the speed of rotation is adjustable to give the desired small-piece size. Figures 4 and 5 show the press itself

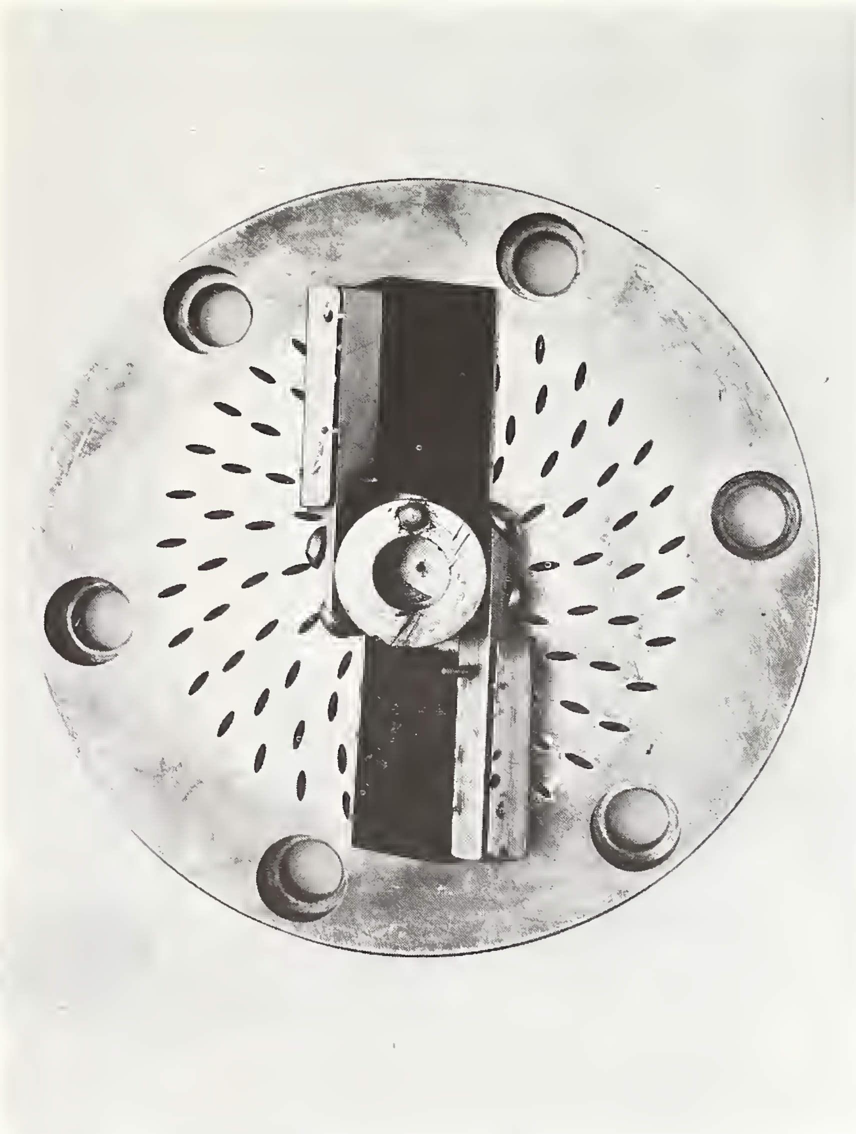

Figure 3. Extrusion plate for macaroni press for making kernel-shaped pieces of dough; cutter rotates on face of die to regulate length of extruded strands.

Figure 4. Laboratory macaroni press in operation to make kernel-shaped pieces from doughs.

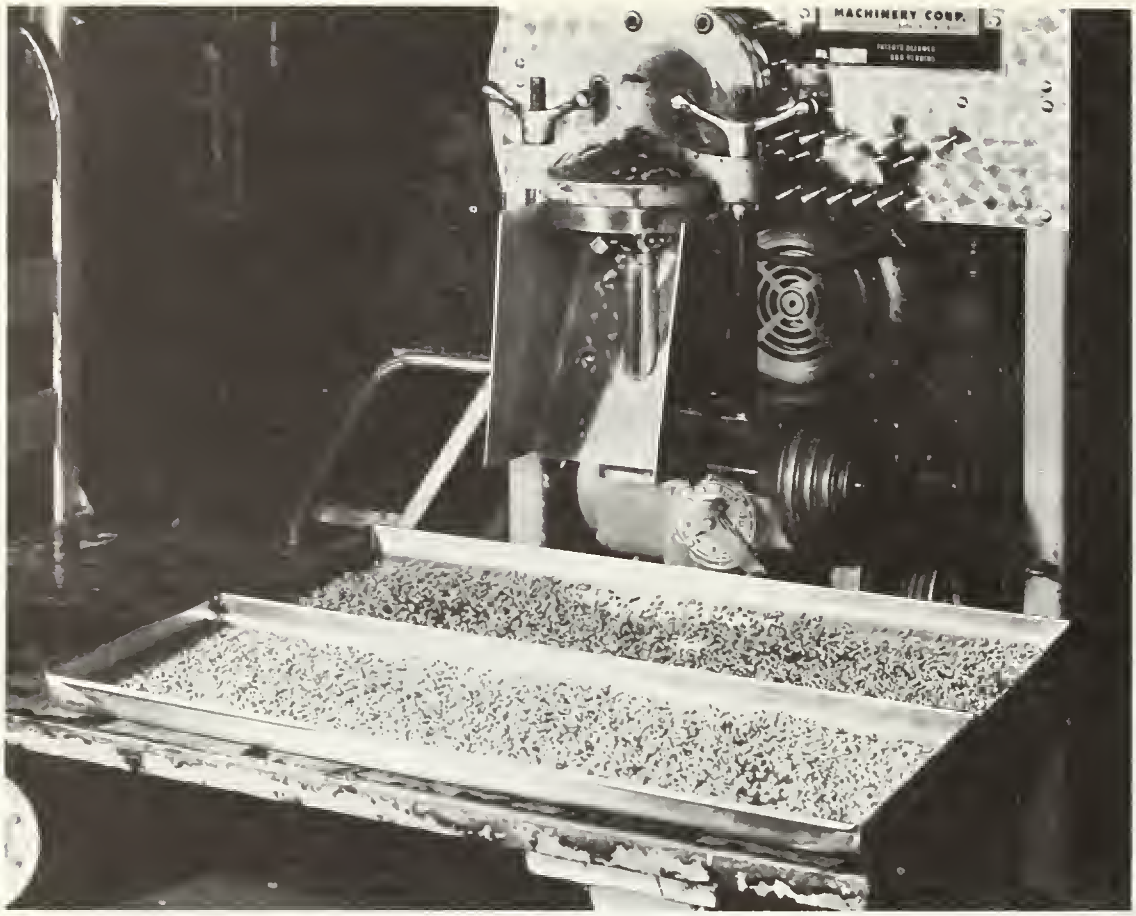

Figure 5. Laboratory macaroni press with horizontally mounted extrusion die to produce kernel-shaped dough pieces.

and how the die is mounted horizontally at the front. The extruded product drops into the pans which then are placed in an oven to dry the product.

Wheat protein concentrate alone may be extruded at about 30 percent moisture content. The amount of gluten in the wheat protein concentrate provides a mechanically strong grain, and one which will retain the grain form when cooked. This product contains over 20 percent protein and has a protein efficiency ratio of about 2.0. If it is desirable, however, to increase the PER to about 2.5, this can be done by additions of other protein sources, such as soy flour. About 25 percent soy flour is required. Other additions to improve nutritional quality, such as vitamins and minerals, are also desirable and quite feasible. Some extruded products are shown in Figure 6.

Our continuing work is concerned with improving the quality of the product in these several ways, plus improving the color, while maintaining desirable cooking characteristics and the necessary physical strength of the dry form.

About this point the question comes up as to why such extruded products should be made with such high contents of wheat protein concentrate, especially if supplemental proteins are to be added. Obviously, the best eating quality for this type of product will be obtained with high levels of durum or other flour that likewise could be supplemented with protein from outside sources.

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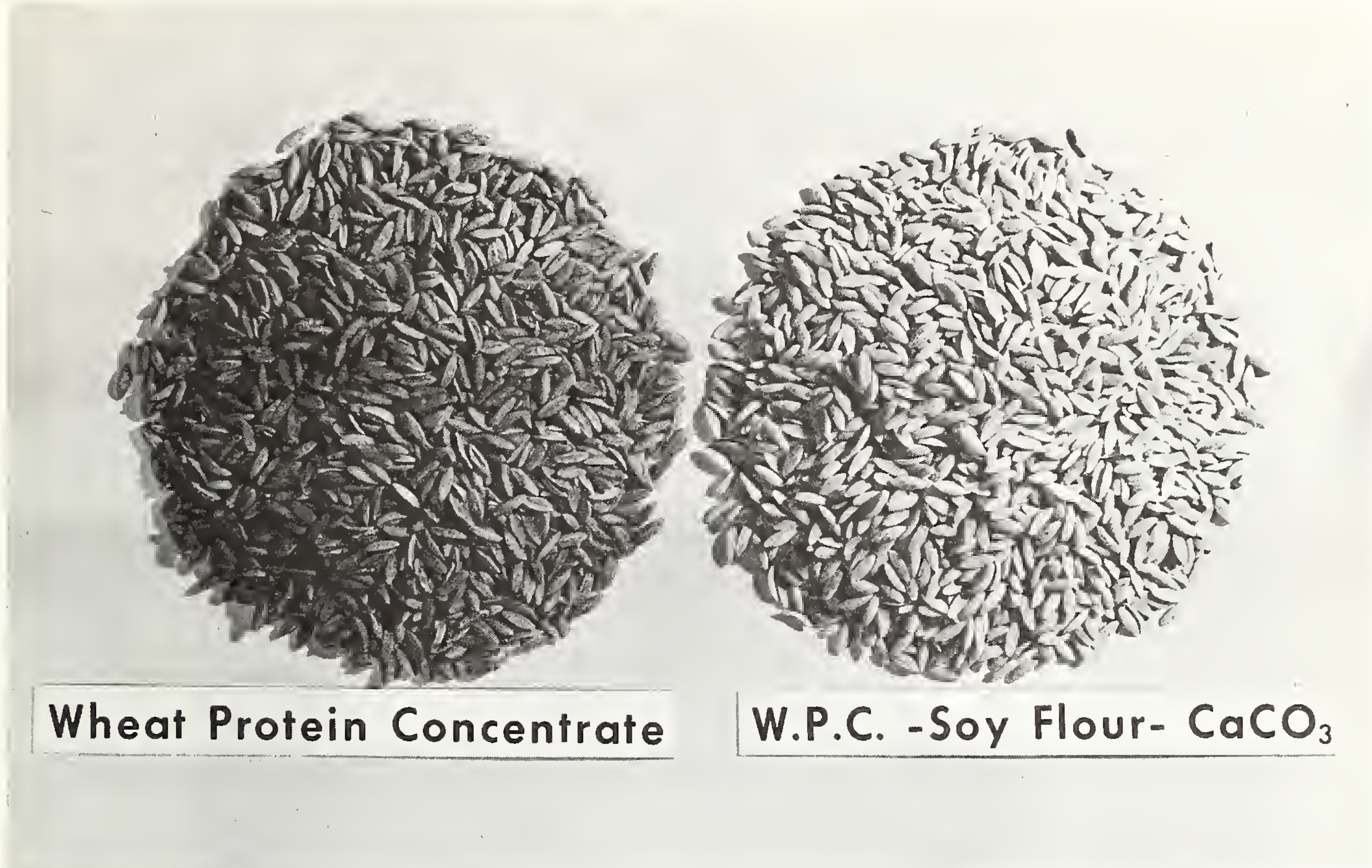

Figure 6. Kernel-shaped extruded pieces of dough from wheat protein concentrate (left) and the protein concentrate mixed with soy flour and calcium carbonate to achieve improved nutritional balance of nutrients (right).

The principal factor to be taken into account, I would judge, is cost of the final product. Very likely, semolina as normally produced would be too costly a starting material to compete with other materials that could be used. What is to prevent, however, using a simplified and cruder way to convert durum into a lower-cost starting material? So long as the fiber content of the durum product can be kept below 1 percent of so, we see no reason why the desirable qualities of durum and other high protein wheats could not be seriously considered in extruded products. The kernel-shaped extruded pieces I have been talking about have a particular attractiveness in some areas overseas. In other areas, however, the more familiar long goods or tubular goods products are probably more acceptable. Fortified pasta products are not a new concept by any means, but at the same time we believe that not all feasible avenues to formulating them have been explored. We intend to continue to explore many combinations of ingredients and variations of many kinds to try to help make this type of product even more widely used and useful than it already is.

Other research at our Laboratory is being directed toward the development of a beverage product with characteristics approaching those of dry milk. This product might be a dry powder which would reconstitute readily in water, or it might be produced in fluid form.

At the Utilization Conference in Boise, 2 years ago, two processes to make this type of product were described. In each process the enzyme pepsin was used to solubilize the protein. The processes differed in the method used to solubilize the starch. In one, amylase was used; in the other, hydrochloric acid.

Since the Boise meeting we have reinvestigated an old method, Fesca's Thin Mash process, for separating or concentrating the protein from wheat flour. Our modification of this process for protein-starch separation was described in a technical paper at the Institute of Food Technologists annual meeting in May of this year. This process is readily applicable, we believe, to preparing high protein milklike products from wheat flour. The modified Fesca process is shown diagrammatically in Figure 7.

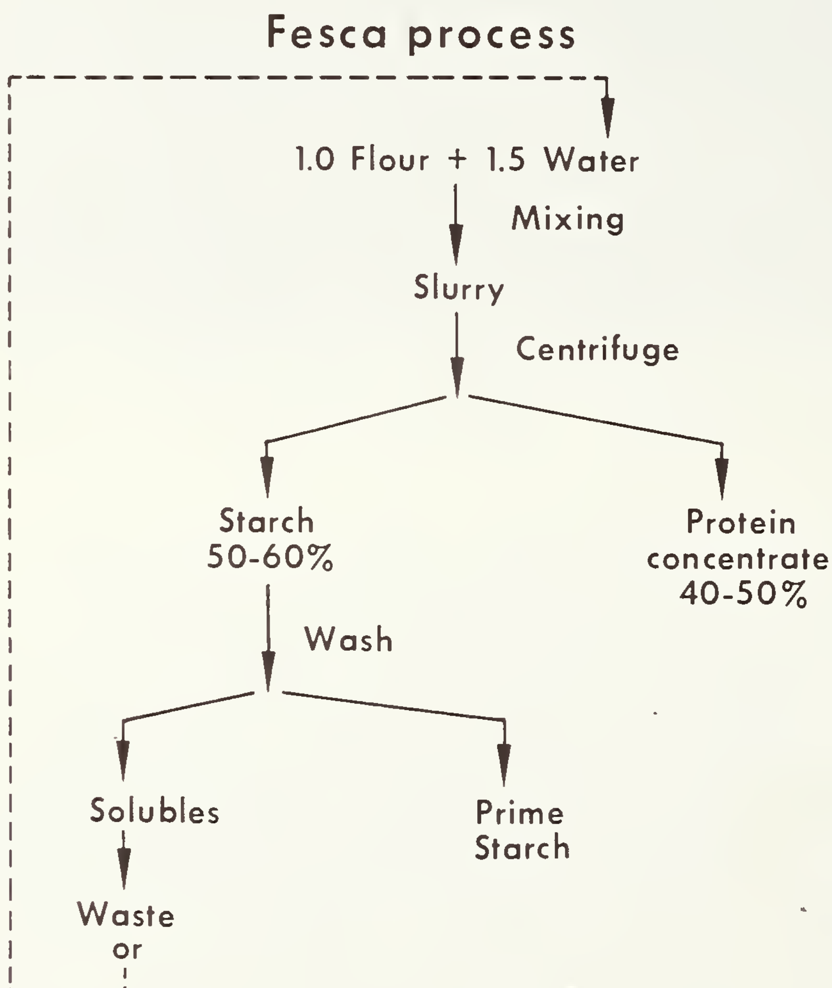

Figure 7. Diagrams of process steps to separate prime starch and concentrate of protein from wheat flour by modified Fesca process.

Flour and water are mixed in a ratio of between 1:1.25 and 1:1.5, depending upon characteristics of the flour. After adequate mixing, the slurry is centrifuged, whereupon two layers form. Such a separation is illustrated in Figure 8. The supernatant in the left-hand vessel contains substantially all

Figure 8. Centrifuged flour slurries showing separation by Fesca method on left, and by mixing which allows gluten to form, on right.

of the protein. The lower layer is almost all prime starch. The supernatant is easily separated by decanting or by other stripping means. Its protein content on a dry basis will be from 20 to 40 percent, depending upon the flour used and the efficiency of separation. In addition to protein, this upper layer contains the "squeegee starch" and water solubles, such as vitamins and minerals. The starch may be washed to yield a high-quality product. The wash water may go to waste or might be used as part of the water used to slurry more flour.

The protein concentrate derived from this process may be used as the starting material for the milklike beverage product. In recent work we have been utilizing another enzyme preparation, a mixture of bacterial proteinases from _B. subtilis_, for solubilizing the protein. It hydrolyzes the protein in a fashion similar to pepsin, which was previously used. That is, it hydrolyzes the protein almost completely without producing very much dialyzable material. This type of hydrolysis is important for maintenance of nutritional and organoleptic quality of the protein. The proteinase from _B. subtilis_ has an advantage over pepsin because its pH optimum is near neutrality, whereas pepsin was only active at quite low pH. Therefore, no pH adjustment and readjustment are required, and off-flavors associated with low pH are avoided.

The new products and the modified products that I have just discussed are in various stages of laboratory development. Some are, perhaps, rather close to commercialization, whereas others are farther away. A great many factors affect the time necessary for a new product to be launched successfully. The products discussed by Dr. Senti and Dr. Johnston are examples of products that have come into being since our last meeting in Boise. With good luck and continued diligence, some of the newer second generation products I have just discussed will be commercial items when we meet again at the next Utilization Research Conference.

ABSTRACTS FOR THE ADVANCEMENT OF INDUSTRIAL UTILIZATION OF WHEAT

Mark F. Adams
Head, Chemical Research, College of Engineering
Washington State University, Pullman, Washington

Any research project is preceded by a thorough literature search. A literature review is necessary, time consuming, and expensive. The abstract journal was proposed to the Washington Wheat Commission late in 1961 with the specific purpose in mind of keeping abreast of current literature, abstracting and compiling this literature, and placing the information in the hands of interested researchers.

The first issue of the journal was published in August 1962, jointly sponsored by the Washington Wheat Commission and by Washington State University.

Of the many projects that we have undertaken in the Chemical Research Section of the College of Engineering Research Division, publication of "Abstracts for the Advancement of Industrial Utilization of Wheat" has been one of the most satisfying, trying, and frustrating of the group.

The name of the journal was generated because very few articles deal specifically with industrial utilization of wheat, and furthermore, our job was to generate interest in the development of the industrial utilization of wheat; therefore, the broader title. You will find in the journal abstracts of articles dealing with industrial utilization of any cereal grain as well as articles on the physical and chemical characteristics of the components of wheat or other cereal products. In this way, we hope to take advantage of the work completed or in progress on agricultural products that could lead to similar or new research on wheat utilization.

In order to make the abstracts readily available for use, a bibliographic outline was developed and each article abstracted was fitted into this outline. Following is the main list of headings. The complete bibliographic breakdown is included in each issue of the journal. Very seldom will you find abstracts under every subject heading in one issue.

1. GENERAL
2. CARBOHYDRATES
    1. Simple Carbohydrates (Mono- and Oligosaccharides)
    2. Miscellaneous Polysaccharides
    3. Starch and Related Products
    4. Cellulose and Related Products
3. PROTEINS, PEPTIDES, AND AMINO ACIDS
4. FATS AND OILS
5. ENZYMES
6. VITAMINS
7. GRAFT POLYMERIZATION
8. MISCELLANEOUS

The abstracting is done by a trained chemist with a background in chemical engineering and paper chemistry. One hundred and forty domestic and foreign scientific journals are searched for pertinent literature. The articles are first selected according to title and then are read to see if they meet the requirements to appear in the journal. Once this selection has been made, the article is abstracted and categorized according to one or more of the subject headings. At the end of a 2-month period, selected abstracts are sorted according to heading number and placed in the hands of the typist who prepares the master copy. The master copy is thoroughly proofread and taken to the University printer where the printing and binding is accomplished. A corrected mailing list is provided to the Duplicating and Mailing Department who then takes care of the stuffing and mailing of the issue.

Even at the outset, we were aware that this abstract journal would have limited subscriber potential. What we did not realize was the stupendous job entailed in searching out and reaching this limited clientele. During the first 2 years, we provided complimentary copies to many Universities, milling companies, chemical industries, and anybody that we could think of that might be interested. As the result of these efforts, we were able to come up with a subscription list of 73.

At this point, the Washington Wheat Commission wanted to know if we were doing any good and if their money was being well spent. We prepared a questionnaire and sent it to each of the 73 subscribers to the journal. Over 75 percent returns were obtained. Figure 1 illustrates the questionnaire with the summation of the answers in the respective squares. As a result of the questionnaire, we were convinced that the journal was being used and was filling a need.

At about this time, the editor decided to add a personal touch to the journal by initiating an editorial page entitled Feature Facts. The idea was to emphasize some particular article or group of articles and to comment on the significance. A good example is the Feature Facts appearing in Issue No. 10 as follows:

> In this issue are abstracted a number of articles appearing in the Proceedings of the First National Conference on Wheat Utilization Research held at Lincoln, Nebraska, in 1962. From the material presented at this meeting, it is noteworthy but not surprising that the bulk of truly industrial utilization research is being carried on at Northern U.S.D.A. Research Laboratories at Peoria, Illinois. The accomplishments of the Northern Research Lab are both timely and outstanding. The brunt of industrial utilization research should not, however, rest entirely on their shoulders. New research teams with new ideas and new approaches should be encouraged and aided in embarking on industrial utilization research.
>
> In the article by H. Wayne Bitting and John R. Matchett, it was pointed out that the major constituents of wheat are starch and

Abstracts for the Advancement of the Industrial Utilization of Wheat

1. Should the Journal be continued? Yes /48/ No /2/ ? /3/
2. If "Yes" why?
   - (a) Practical application has been made of the information /15/
   - (b) Unique compilation of related subject matter /24/
   - (c) New Journal and may contain valuable information /11/
   - (d) Has permanent reference value /28/
   - (e) Other: (specify on back of page) /1/
3. How many individuals in your organization use the Journal?
   1-5 /22/ 5-10 /12/ 10-15 /2/ 15 or more /5/
4. Would you continue your subscription if the rate were increased to:
   $12 /14/ $18 /10/ $24 /10/ $30 /6/ $60 /2/ per year.
   would possibly subscribe to 2 copies.
5. How has the Journal been of value to you? (check one or more)
   - (a) Regular, as immediate information source /23/
   - (b) Source of ideas for Industrial Utilization of wheat /12/
   - (c) Source of ideas for Industrial Utilization of other projects /15/
   - (d) General information for other projects /17/
   - (e) Library source material /23/
   - (f) Other: (use back of page) /2/
6. How can the Journal be improved?
   - (a) Cover more areas: Yes /5/ No /21/
     (If "Yes" please specify on back of page) ______
   - (b) "Feature Facts": Expand /4/ As is /19/ Drop /2/
   - (c) Publish: Monthly /5/ As is /24/ Quarterly /5/ Semi-annually /0/
   - (d) Index: Drop /0/ As is /21/ More detail /39/ Other: ______
   - (e) Other suggestions: (please use back of sheet) ______
7. Comments: ______
8. NAME: ______
   TITLE: ______
   COMPANY: ______
   STREET NO.: ______
   CITY: ______ STATE: ______ ZIP CODE: ______

Figure 1. Evaluation Questionnaire

protein with lesser amounts of oil and nonstarch carbohydrates. Of these components, the protein (gluten) is the one major constituent that is unique to wheat. Bitting and Matchett stated the situation very well.

> Wheat gluten is a protein which is unique in its ability to form a cohesive, elastic mass when mixed with water. Although this distinguishing characteristic is utilized when producing bread and other baked goods, little is known about its special physical properties. Insufficient research has been made to exploit these properties in diverse industrial outlets, finding new high value uses for gluten, as is, or after chemical modification is the key to industrial utilization of wheat.

The wheat industry itself must carry the ball both by initiating and financing industrial utilization research. The fundamental and applied research data must be on hand when industry "discovers" the "miraculous" properties of gluten, of wheat starch, and other constituents of the wheat berry.

After we had gotten well underway and overcome most of our growing pains, we turned to the job of abstracting all of the most pertinent literature from the period 1940 to 1962. This was published as a special issue and mailed to each of the subscribers. It was surprising to find the great growth of literature pertaining to industrial utilization of wheat over this 20-year period.

In order to increase the usefulness of the abstract service, we started a subject and author index with Volume 3. As time permitted, we prepared an index for Volumes 1 and 2 so that all volumes now have a subject and author index. We made the index as simple as possible by listing the chronological abstract number, the title, and the author under each bibliographic subject heading. In this way, articles dealing with a specific subject can be located. If more information is desired, the original abstract can be found by referring to the issue number and abstract number. From here, the researcher can go to the original article on the subject.

At the outset, the subscription price was arbitrarily set at $9.00 per volume. As a result of the response obtained to the questionnaire, the subscription price was increased to $13.50 domestic and $14.00 foreign starting with Volume 5 (July 1, 1966).

We currently have 217 subscribers and a current growth rate of about 20 percent per year. Of the 217 subscriptions, 83 are from foreign countries. Following is a list of these countries with the total subscriptions in each:

Australia	11	Germany	9	Peru	1
Canada	11	Holland	2	Scotland	1
Chile	1	India	2	South Africa	2
Denmark	2	Ireland	3	Spain	1
England	3	Israel	1	Sweden	5
Finland	2	Italy	6	Switzerland	2
France	10	Japan	6	U.S.S.R.	2

I spoke to you earlier about the problems in reaching potential subscribers. Starting with Volume 4, we came up with the idea of soliciting the authors of each article abstracted in the journal by sending them a complimentary copy of the issue along with a subscription blank. We have found that a great number of the articles abstracted have been by foreign authors; thus, the foreign contact.

Of 800 abstracts included in the journal, 185 were directly related to wheat and 609 were indirectly related to wheat. Of those directly related to wheat, 73 were by U.S. authors and 112 were by foreign authors from 19 different countries. Of the articles indirectly related to wheat, 269 were by U.S. authors and 340 by foreign authors from 31 different countries.

At the outset, we had as an objective a compilation of information to assist in literature search. We have just completed a prime example of such a search. This is a 21 page manuscript on "Developments in the Preparation of Starch Adhesives." All of the articles in the review were obtained from the abstract journal. The chapter headings in the manuscript are as follows:

I. Hydrolysis of Starch
II. Gelatinization of Starch Either with Heat or Chemicals
III. Starch and Resin Combinations
IV. Glyoxal as an Insolubilizing Agent
V. Dialdehyde Starch Adhesives
VI. Metal Salts as Insolubilizers
VII. Cationic Starch Binders
VIII. Modified Starch Adhesives
IX. Miscellaneous Types of Starch Adhesives

This will be published as a bulletin of the College of Engineering Research Division for general distribution.

EFFECT OF PROTEIN CONTENT IN WINTER WHEATS ON LEVELS OF ESSENTIAL AMINO ACIDS

P. J. Mattern, V. A. Johnson, D. A. Whited, and J. W. Schmidt
Crops Research Division, USDA, and the University of Nebraska,
Lincoln, Nebraska

The importance of wheat as a human food in the world is equal to that of rice. Countless millions of people rely upon wheat for their daily sustenance. The protein of wheat possesses unique physical properties that permit the use of leavening agents to produce palatable and highly desirable bread foods.

Wheat, like all of the other major cereal food crops (rice, corn, sorghum), lacks the amino acid balance necessary for maximum utilization of its protein for tissue synthesis and body growth. It is most deficient in the amino acids lysine, methionine, and threonine probably in that order.

Improvement of wheat nutritionally can be accomplished in different ways. The first and obvious approach is to increase its protein content. If the increase is not associated with a less desirable ratio or balance of the essential amino acids, the higher protein content would have the effect of providing more of these essential amino acids per unit quantity of wheat consumed. A second approach would be to improve the ratio of essential amino acids in the wheat protein. For example, more lysine in wheat protein would permit the protein to be more fully utilized to satisfy nutritional requirements. Lysine and other limiting essential amino acids can be added directly to the processed wheat. This approach encounters serious difficulties of implementation in countries where there is greatest reliance on wheat as the main food staple.

Quality of protein in wheat from a nutritional viewpoint has received little serious attention until recent years. The pressure of rapidly increasing world population and widespread food shortages in many countries has provided the impetus for much accelerated research into the nutritional quality of wheat and other cereals. The recent discovery by Nelson and Mertz of Purdue University of a gene in corn that significantly increases the lysine content of corn protein has stimulated the search for genes with similar effect in the other cereal crops.

The Agricultural Research Service and the Nebraska Agricultural Experiment Station have engaged in cooperative research on wheat protein since 1955. Initially, the research centered around the establishment of the effectiveness of genes for higher protein in wheat and the transfer of these genes into winter bread wheats. Subsequent research has been concerned with physiological aspects of the high protein phenomenon in wheat and the study of amino acid composition of high protein lines.

We are currently engaged in the systematic screening of some 17,000 wheats in the World Wheat Collection for significant and useful differences in protein and lysine content.

Quantity of protein. When Atlas 66 was used as a source of high protein in crosses with the hard winter wheat Comanche, the F_2 population gave a near-normal frequency distribution (Figure 1). The parental varieties were widely different in protein content of their grain and the F_2 mean was intermediate to the parents.

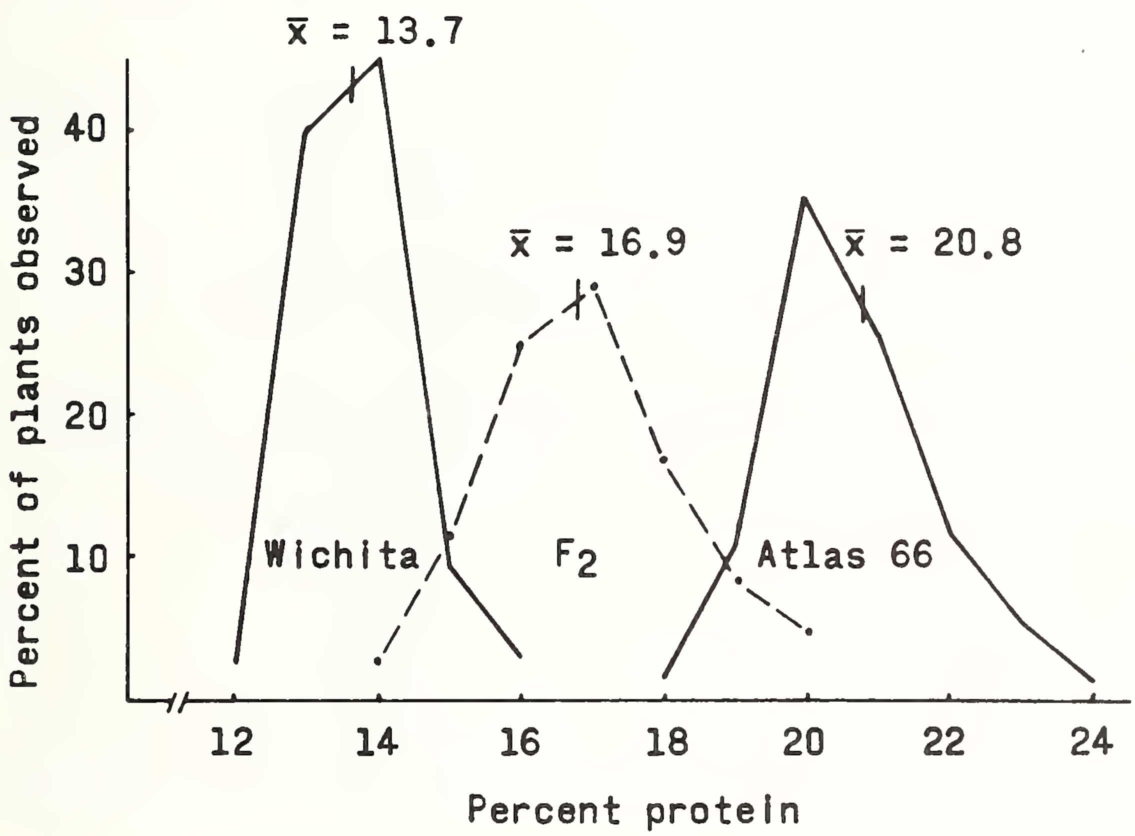

Figure 1. Grain protein frequency distribution of plants of Wichita and Atlas 66 and their F_2 generation grown at Lincoln, Nebraska, in 1957.

Atlas 66 possesses adult resistance to leaf rust. Its gene for resistance is linked with a gene for high protein. Resistant segregates averaged 17.0 percent protein whereas susceptible segregates averaged only 13.5 percent protein (Figure 2). There also appears to be some linkage of high protein with soft grain texture and low adult resistance or tolerance to stem rust.

A number of advanced selections from crosses of Atlas 66 with Wichita and Comanche were evaluated in 1965 (Table 1). Atlas 66 was 4 percent higher in protein than Comanche and Wichita. Progeny lines ranged from 15.3 to 18.7 percent protein with a mean of 16.9 percent.

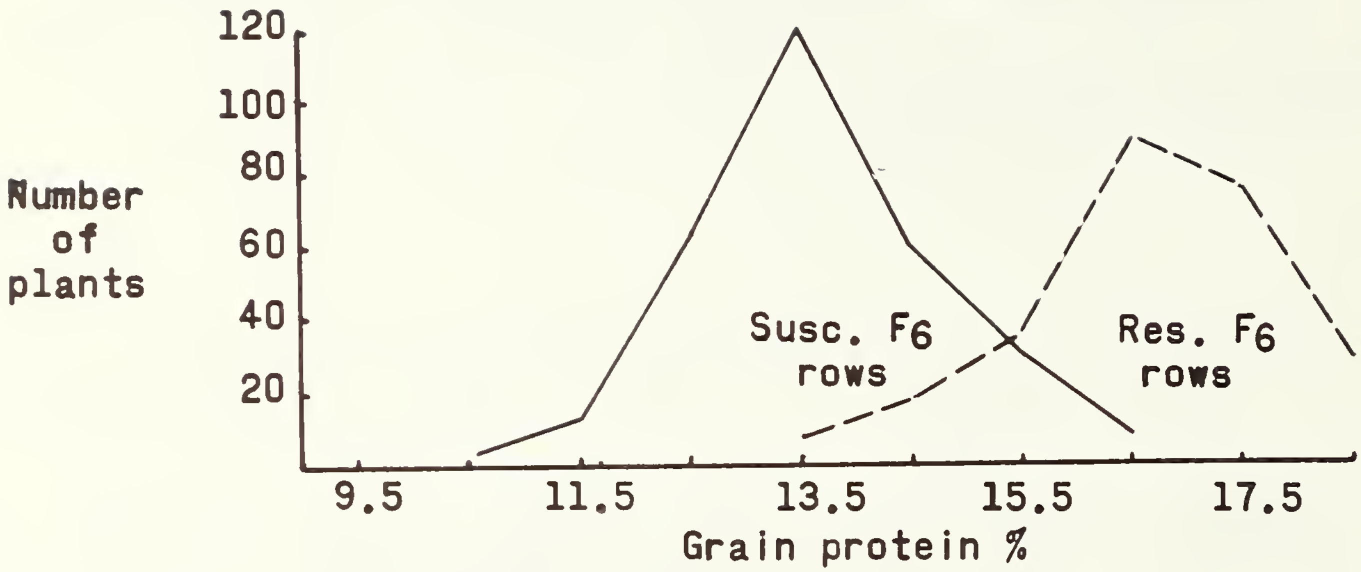

Figure 2. Grain protein frequency distribution of F_6 rows of Atlas 66 X Wichita homozygous for reaction of leaf rust.

Table 1.--Grain protein content of parent varieties and high protein progeny lines grown at Lincoln, Nebraska, in 1965

Item	Protein, %
Atlas 66	18.3
Wichita	14.0
Comanche	14.3
Progeny lines (range)	15.3-18.7
Progeny lines (mean)	16.9

In 1966 Comanche was higher in protein than in 1965, but it was 3.3 percent lower than Atlas 66 (Table 2). High protein progeny lines ranged from 16.2 to 18.3 percent protein in their grain with a mean of 17.4 percent.

Table 2.--Grain protein content of parent varieties and high protein progeny lines grown at Lincoln, Nebraska, in 1966

Item	Protein, %
Atlas 66	18.3
Wichita	14.1
Comanche	15.0
Progeny lines (range)	16.2-18.3
Progeny lines (mean)	17.4

The percentage increase in protein among the high protein lines over the Comanche and Wichita parent varieties in 1965 and 1966 is shown in Table 3. As much as 30.7 percent increase (Atlas 66 X Comanche) was recorded in 1965 and 26.5 percent (Atlas 66 X Wichita) in 1966.

Table 3.--Percentage increase in the protein content of high protein progeny lines over their low protein parent

Progeny lines	1965	1966
Atlas 66 X Comanche lines	6.7-30.7	7.6-21.7
Atlas 66 X Wichita lines	12.1-19.9	22.5-26.5

High protein wheat would have little practical value if it was less productive than other wheat. Our results have indicated that higher protein levels can be achieved by breeding without sacrificing yield. Note in Table 4 that the high protein lines 60306 and 60305 were intermediate in yield to the varieties Scout and Warrior and their grain possessed as much as 3 percent more protein.

Table 4.--Average heading date, grain yield, and grain protein content of Scout, Warrior, and the high protein selections 60305 and 60306 at Lincoln, Nebraska, 1962-1964

Variety	Date headed, May	Grain yield, bu./acre	Protein content,1/ %
Scout	19	41	13.6
60306	19	38	16.1
60305	22	36	16.5
Warrior	22	31	13.4

1/ Calculated at 14 percent moisture.

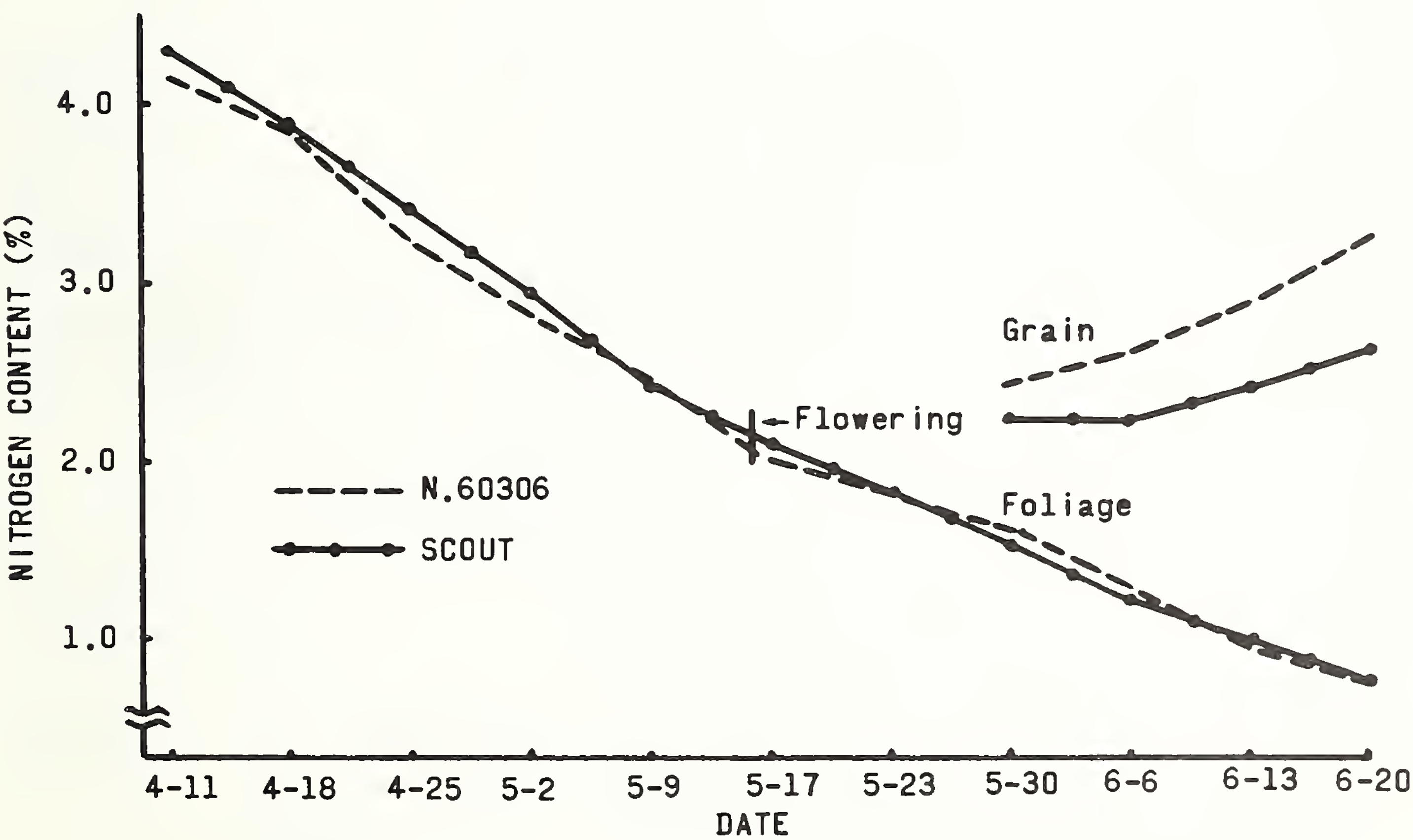

Figure 3. Nitrogen content of the foliage and grain of two winter wheat varieties at Lincoln, Nebraska, 1963.

Physiologic basis for high protein. In order to learn something of the physiologic basis for the high protein phenomenon in wheat, the nitrogen content of the plants and grain of high and low protein varieties was assayed at weekly intervals. As soon after anthesis as the developing grain could be separated from other plant parts, it was analyzed separately.

Nitrogen relations in the high protein selection 60306 are compared with the variety Scout in Figure 3. At no time during the spring growing season were there significant differences in the plant nitrogen content of the two varieties. Yet, from the early stages of kernel development, the grain of 60206 had a higher nitrogen content than the grain of Scout. Nitrogen increased in the grain of both varieties as kernel development progressed, but the rate of increase was more rapid in 60306.

Warrior characteristically produces moderately low protein grain. Yet, when compared with high protein selection 60305, the plants of Warrior contained significantly more nitrogen than 60305 at all sampling dates throughout the spring (Figure 4). Selection 60305, with a much lower plant nitrogen content, produced grain with significantly higher nitrogen content at all stages of kernel development.

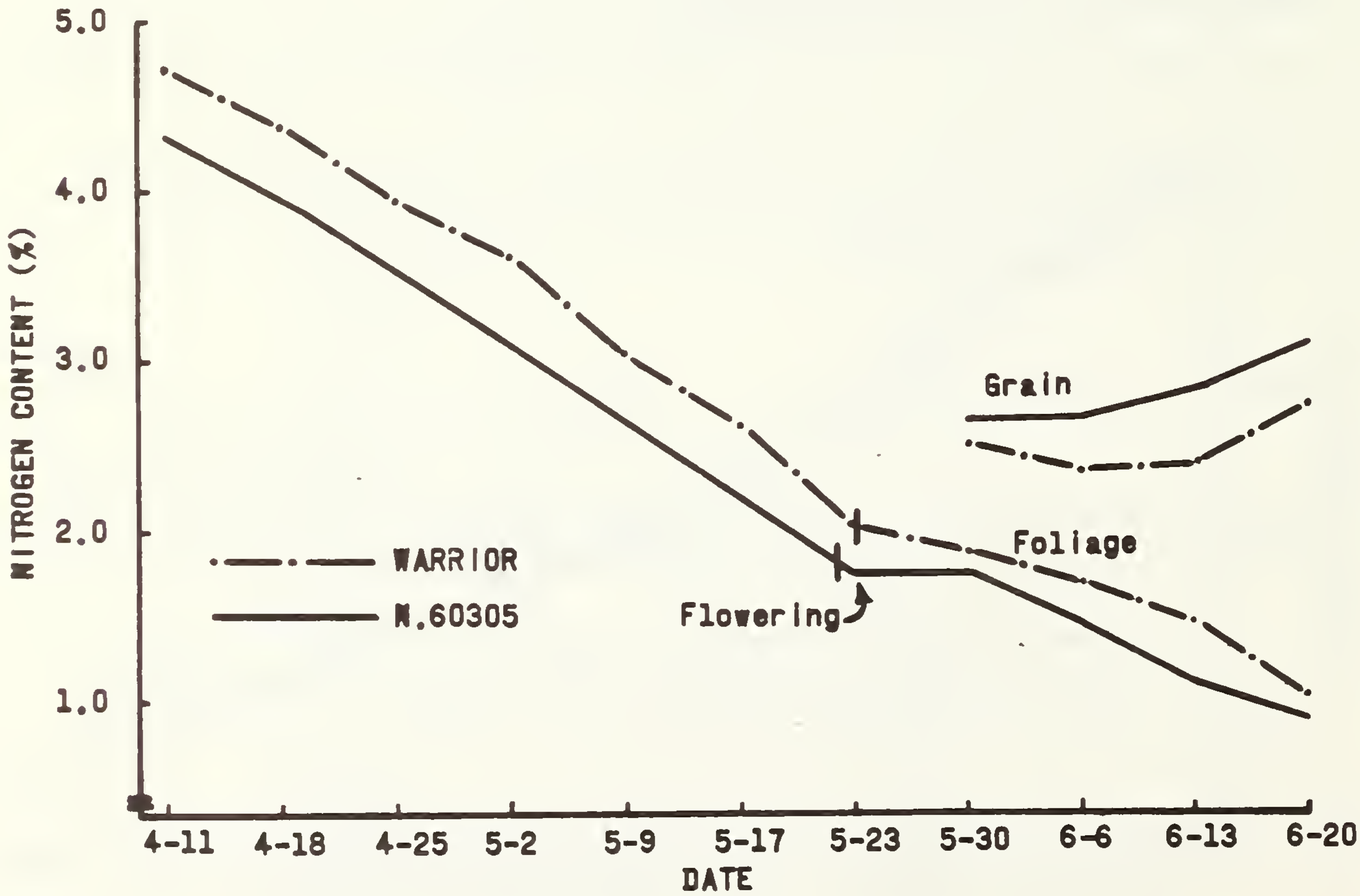

Figure 4. Nitrogen content of the foliage and grain of two winter wheat varieties at Lincoln, Nebraska, 1963.

Our data suggest that the high protein genetic trait in wheat is not associated with differential nitrogen uptake or nitrogen accumulation in the plant. Varieties may differ in their plant nitrogen content but such differences appear to be unrelated to inherent grain protein differences. More complete and efficient translocation of nitrogen from the plant to its grain seems to be the physiologic basis of high grain protein.

Nutritional quality of the protein. The balance of essential amino acids determines the nutritional value of protein since the protein is utilized in relation to the level of its first limiting essential amino acid. If high protein wheats possessed a less favorable balance of the essential amino acids, their nutritional value would be decreased. Lysine, methionine, and threonine are particularly critical since they are the most deficient in wheat. The levels of these amino acids in selected high protein lines of Atlas 66 X Comanche are compared with the parent varieties in Table 5. Atlas 66 and Comanche are similar in lysine and threonine but Atlas 66 is substantially the lowest in methionine. All of the experimental lines are comparable to the parent varieties in lysine. Line 2507 is considerably higher in lysine than either parent. Most lines are as high in methionine as Comanche. Three lines are lower in threonine than either parent variety. Line 2509 exhibits the best balance of all three amino acids.

Table 5.--Lysine, methionine, and threonine levels in selected high protein lines of Atlas 66 X Comanche

Variety	Protein, % DWB[1]	Lysine, % protein	Methionine, % protein	Threonine, % protein
Comanche	15.0	3.23	1.67	3.54
Atlas 66	18.0	3.33	1.11	3.35
Atlas 66 X Comanche 2507	17.7	3.72	1.74	2.62
Atlas 66 X Comanche 2509	18.3	3.45	1.83	3.32
Atlas 66 X Comanche 2504	17.9	3.38	1.14	3.69
Atlas 66 X Comanche 2510	16.5	3.37	1.67	3.22
Atlas 66 X Comanche 2499	18.2	3.29	1.68	3.10
Atlas 66 X Comanche 2500	18.3	3.20	1.65	3.16

1/Percent of total dry weight.

Among 17 high-protein Atlas 66 X Comanche and Atlas 66 X Wichita lines studied, the range in lysine (expressed as percent of protein) was from 6.5 less to 13.0 percent more than the low-protein parents Comanche and Wichita (Table 6.) For methionine the range was from -31.7 to +13.8 percent and for threonine it was from -26.0 to +4.2 percent. Lysine content among 17 lines averaged 5.0 percent more than the low protein parent but methionine averaged 0.8 percent less and threonine 9.1 percent less than the low protein parent.

Table 6.--Percent increase in amino acid content (g./100 g. protein) of 17 high-protein lines over their low-protein parent

Amino acid	Range	$\bar{x}$
Lysine	-6.5 to 13.0	+5.0
Methionine	-31.7 to 13.8	-0.8
Threonine	-26.0 to 4.2	-9.1

To adequately assess the contribution of higher protein to the nutritional value of wheat, it is necessary to measure amino acid levels on a grain weight basis. Values shown in Table 7 were calculated on a grain weight basis. The 17 high-protein lines averaged 22.3 percent more lysine, 15.7 percent more methionine, and 7.7 percent more threonine than contained in the low-protein hard wheat parents.

Table 7.--Percent increase in amino acid content per unit weight of grain among 17 high-protein lines over their low-protein parent

Amino acid	Range	$\bar{x}$
Lysine	8.0 to 34.7	22.3
Methionine	-21.0 to 33.1	15.7
Threonine	-3.9 to 24.2	7.7

All essential amino acids except tryptophan were analyzed in 17 high-protein lines. The amount of each amino acid in relation to Comanche is shown for Selection 2509 in Table 8. Note that Selection 2509 contained 22 percent more protein than Comanche. It was equal to or better than Comanche in all essential amino acids except threonine (9 percent less) and phenylalinine (2 percent less).

Table 8.--Protein and essential amino acid (g./100 g. protein) in Atlas 66 X Comanche Selection 2509

Percent higher or lower than Comanche in:	
Total protein	+22
Lysine	+7
Methionine	+10
Threonine	-9
Histidine	+10
Valine	+2
Isoleucine	0
Leucine	+2
Phenylalinine	-2
Tryptophan	Not analyzed

Similar information for Selection 2507 is shown in Table 9. Although it is only 14 percent higher in protein than Comanche, Selection 2507 exhibits considerably poorer amino acid balance than Selection 2509. It has 26 percent less threonine than Comanche and 5 percent less phenylalinine. The apparent deficiency of threonine is particularly important since it is the third most limiting essential amino acid in wheat. The lysine content of 2507 was 15 percent higher than Comanche.

It seems clear from our data that high protein in wheat need not be associated with an altered, less favorable amino acid balance. In our high protein Atlas 66-derived lines there has been no nutritional penalty in lysine and methionine and only a small one in threonine. Our data suggest the possibility of effective selection for improved amino acid balance in our high protein materials.

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Table 9.--Protein and essential amino acid (g./100 g. protein) in Atlas 66 X Comanche Selection 2507

Percent higher or lower than Comanche in:	
Total protein	+14
Lysine	+15
Methionine	+4
Threonine	-26
Histidine	+6
Valine	+3
Isoleucine	+3
Leucine	0
Phenylalinine	-5
Tryptophan	Not analyzed

The Nebraska Experiment Station in cooperation with the Agricultural Research Service is systematically analyzing all of the common wheats in the World Collection maintained by the U.S. Department of Agriculture to identify new sources of high protein and high lysine. The research is being supported by the Agency for International Development, U.S. State Department. More than 2,000 wheats from the Collection have been analyzed to date.

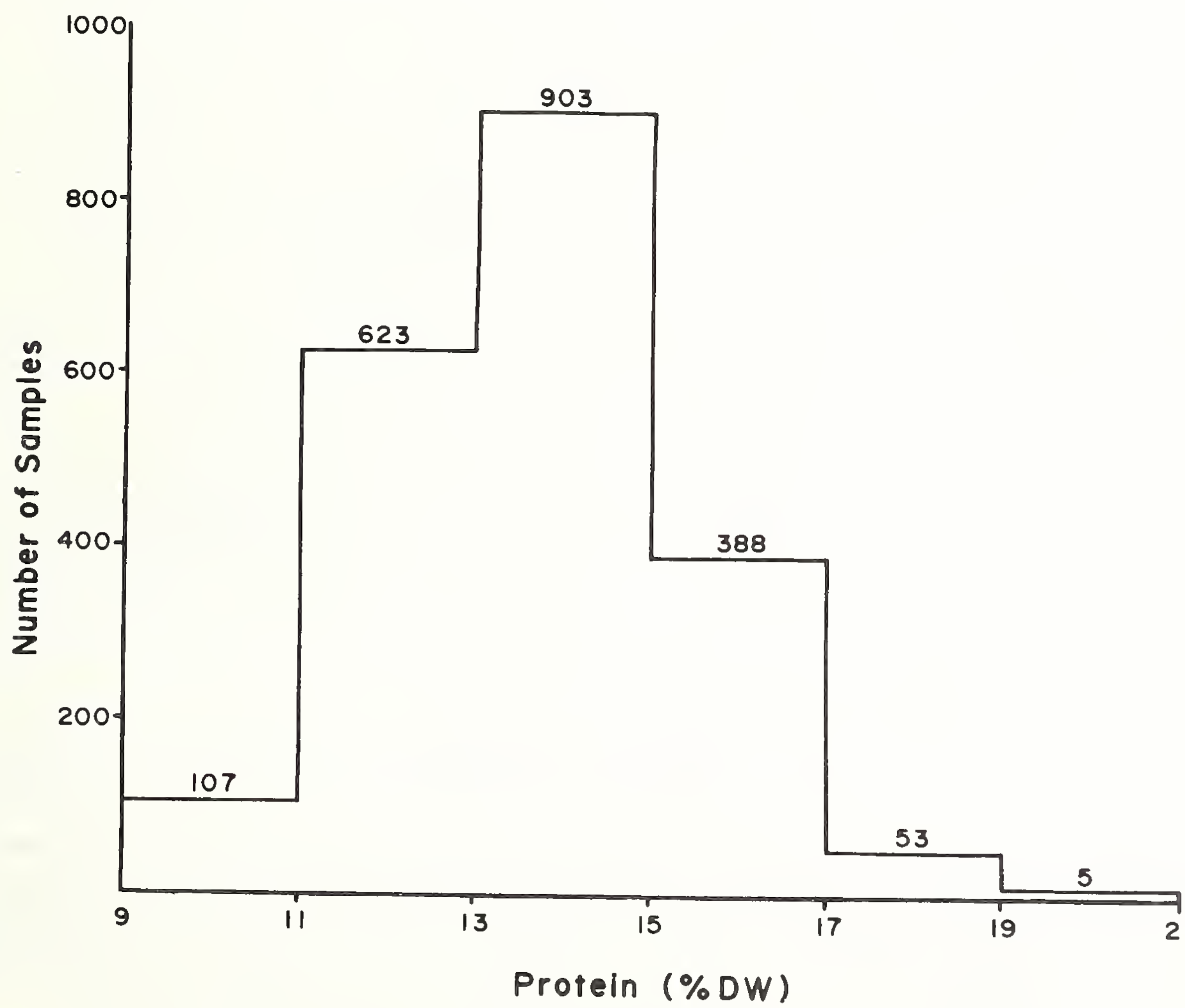

Figure 5. Protein (percent of dry weight) frequency distribution for 2079 wheats from the World Collection.

The protein frequency distribution for 2,079 wheats is shown in Figure 5. The largest number of samples fell in the 13-to 15-percent protein class. Only 58 had a protein content of 17 percent or more while 107 were below 11 percent in protein.

The frequency distribution for lysine expressed as percent of protein appears in Figure 6. More than one-half of the samples possessed lysine in the range of 2.9 to 3.2 percent. Forty-one samples exceeded 3.5 percent and only six were less than 2.3 percent in lysine.

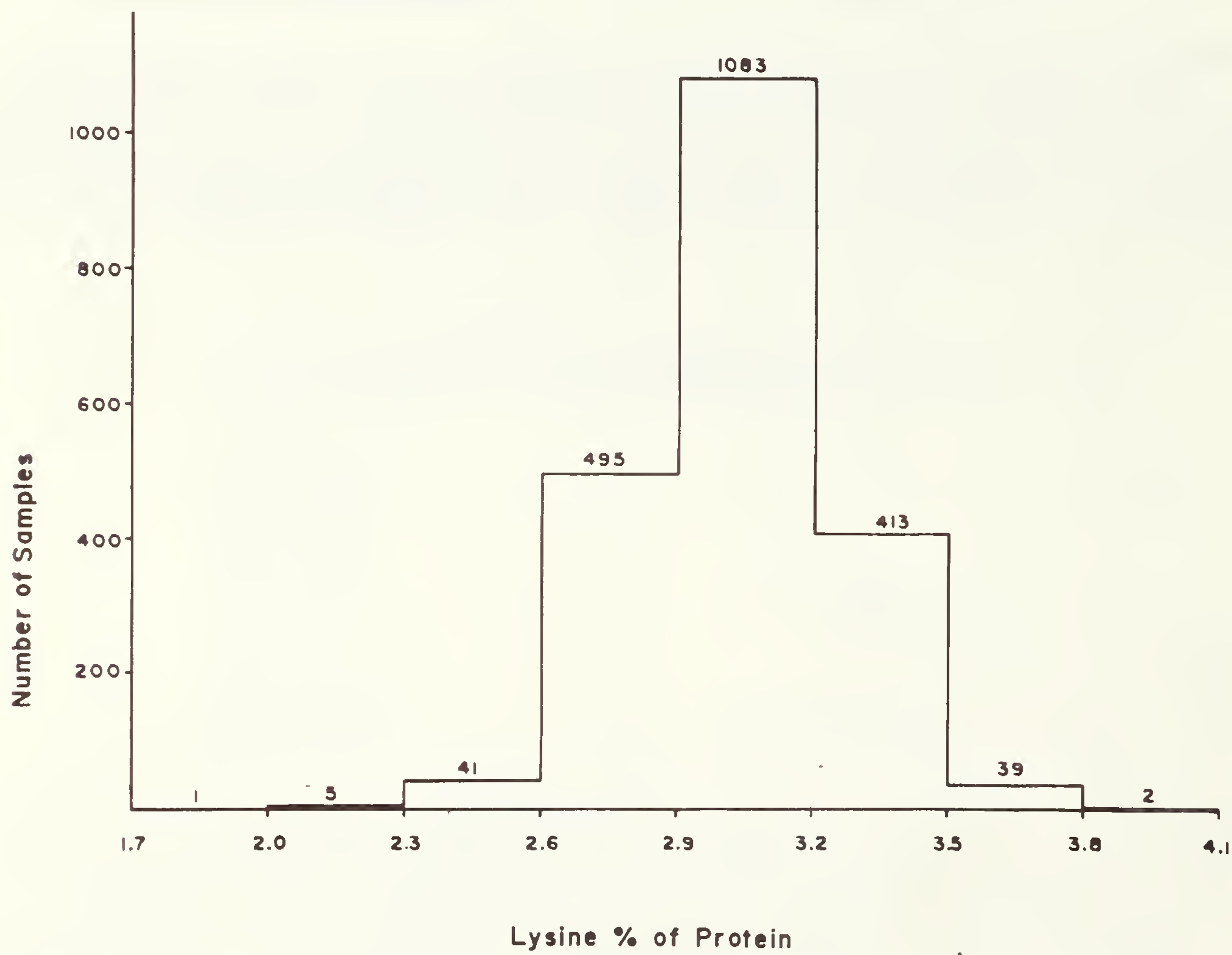

Figure 6. Lysine (percent of protein) frequency distribution for 2,079 wheats from the World Collection.

The effect of protein level on mean lysine content expressed as percent of total dry weight is shown graphically in Figure 7. The shaded area indicates the range of lysine variation encountered at each protein level. Note the very uniform and substantial increase in lysine with protein. This would be expected since lysine is a constituent of protein and thus would be affected by changes in protein.

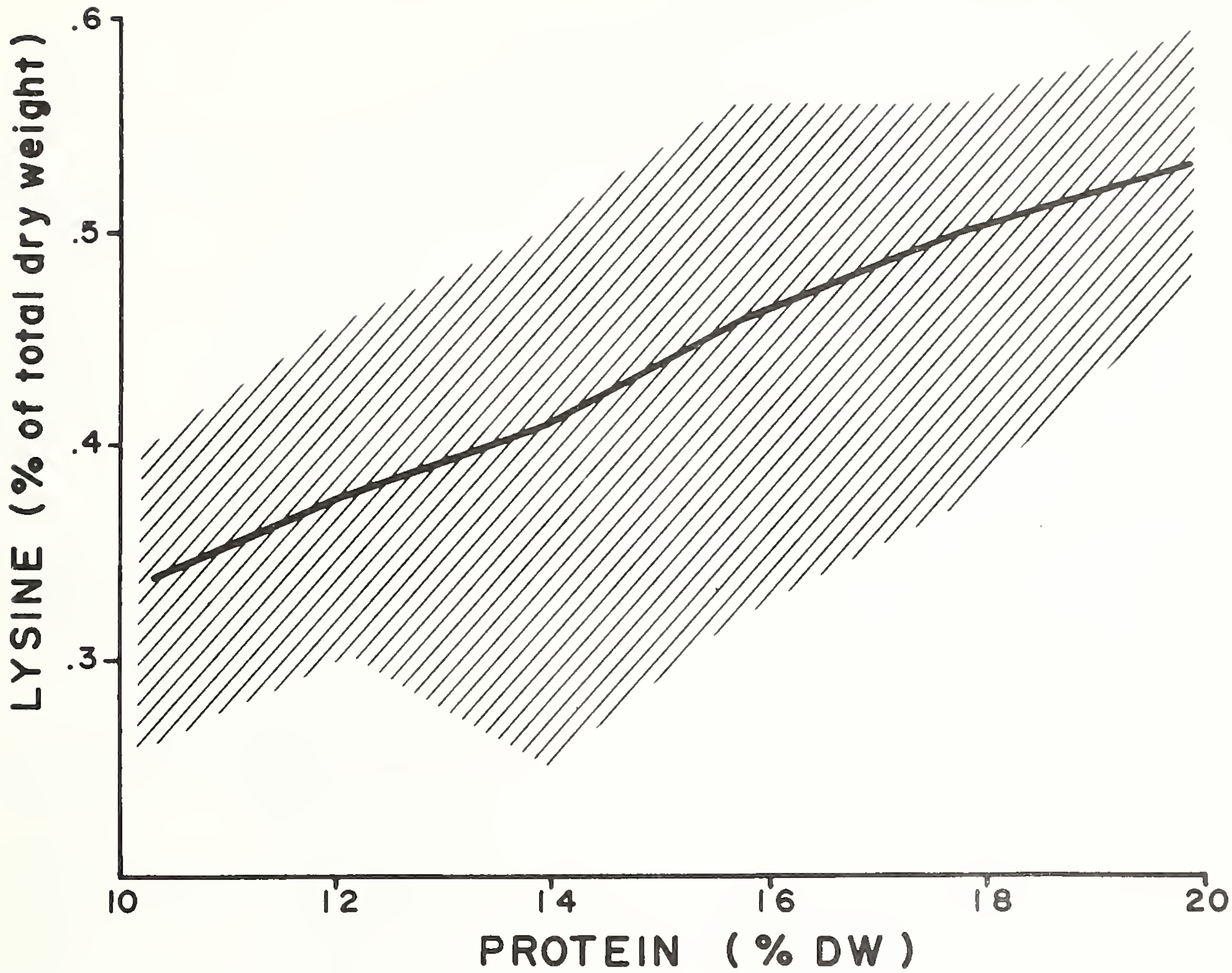

Figure 7. Relationship of lysine (percent of total dry weight) to protein among 2,079 wheats from the World Collection.

When lysine is expressed as percent of protein, its relationship with protein over a range of protein values is a negative one (Figure 8). However, the effect of protein level on lysine is relatively modest. Average lysine content decreased from 3.31 percent at 10.3 percent protein to 2.71 percent at 19.9 percent protein among 2,079 wheats analyzed. The decrease in lysine appears to be somewhat largest in the 10 to 14 percent protein range.

The correlation of protein with lysine (expressed as percent of dry weight) over the entire range of protein encountered among 2,079 wheats was +0.81 (Table 10). However, the correlation of lysine with protein within 2 percent protein increments is relatively modest--ranging from +0.46 in the 13.0 to 14.9 percent protein level to only +0.03 at the 17.0 to 18.9 percent protein level. This would indicate that lysine variation within restricted ranges of protein is largely random.

A low negative correlation of -0.48 was obtained when lysine as a percent of protein was correlated with protein (Table 11). The correlations were even lower when correlations were based on samples within restricted protein ranges.

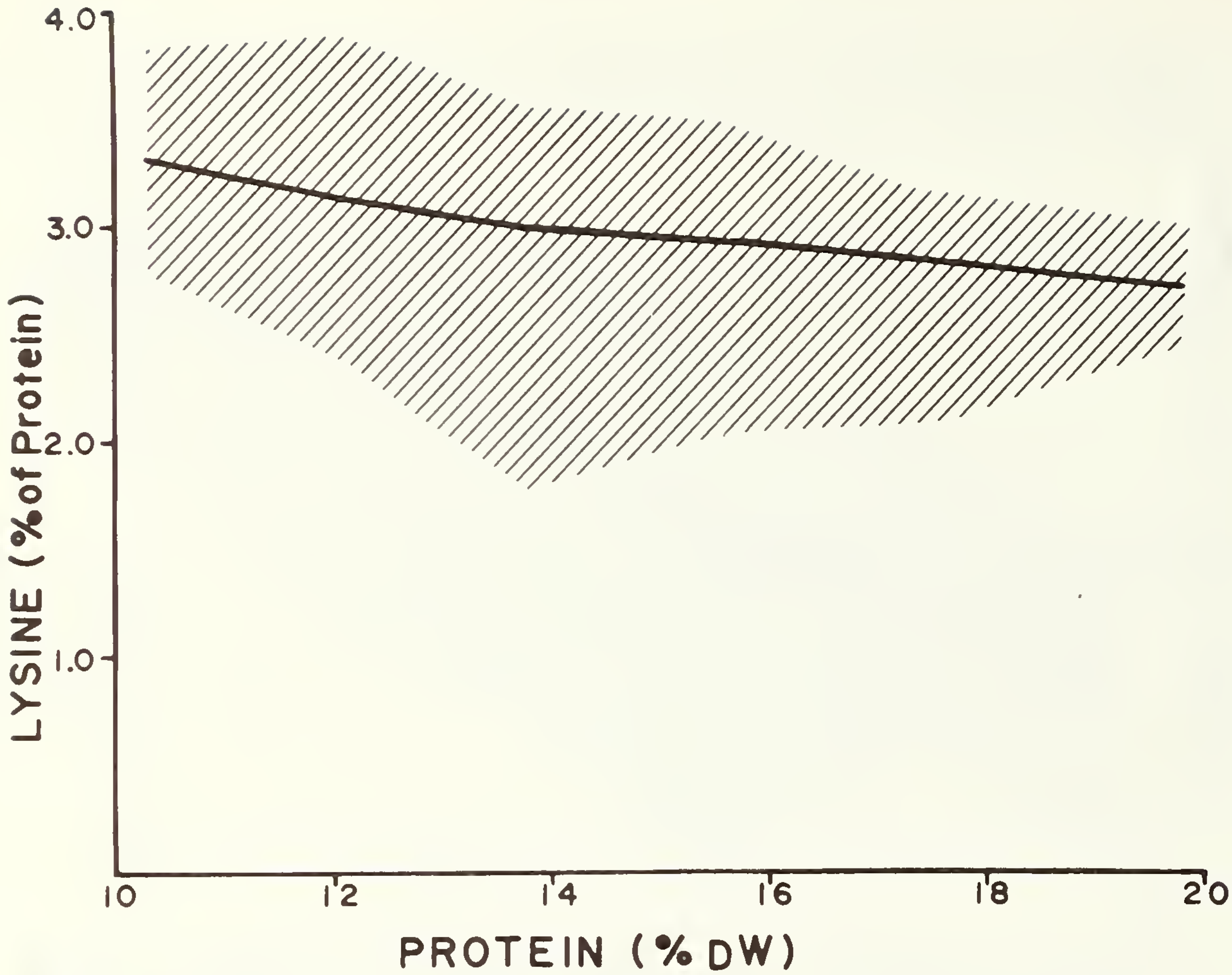

Figure 8. Relationship of lysine (percent of protein) to protein among 2,079 wheats from the World Collection.

Table 10.--Correlation of protein and lysine expressed as percent of dry weight of grain

Protein range, %	n	r
9.0 to 21.0	2,079	+0.81
9.0 to 10.9	107	+0.40
11.0 to 12.9	623	+0.34
13.0 to 14.9	903	+0.46
15.0 to 16.9	388	+0.34
17.0 to 18.9	53	+0.03

Table 11.--Correlation of protein and lysine expressed as percent of protein

Protein range, %	n	r
9.0 to 21.0	2,079	-0.48
9.0 to 10.9	107	-0.29
11.0 to 12.9	623	-0.33
13.0 to 14.9	903	-0.11
15.0 to 16.9	388	-0.14
17.0 to 18.9	53	-0.34

Our data indicate that level of lysine is influenced by protein level but that protein can account for only a portion of the lysine variation we have encountered. Thus, it would seem that selection for high lysine in wheat may be feasible.

The protein and lysine contents of selected wheats from the World Collection are shown in Table 12. The mean protein content of 2,079 wheats from the World Collection was 13.6 percent. Lysine expressed as percent of protein averaged 3.04 percent. The lowest lysine encountered was 1.77 percent in a 14.3 percent protein wheat from Russia. Seven of the wheats included in Table 12 appear to have promise as possible sources of high lysine. None is abnormally low in protein and two are higher in protein than the average of the 2,079 wheats analyzed.

Table 12.--Protein and lysine content of selected wheats from the World Collection

Sample No.	Origin	Protein,[1/] %	Lysine Dry wt., %	Lysine Protein, %
1180	USA	11.5	0.44	3.87
22	Arabia	12.1	0.44	3.66
15	USA	12.5	0.46	3.65
667	China	12.5	0.45	3.58
610	Sweden	13.3	0.47	3.57
20	Spain	15.1	0.52	3.44
1335	USA	14.1	0.47	3.36
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$\bar{x}$ (2079 samples)		13.6	0.40	3.04
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229		14.3	0.25	1.77

1/ Dry weight basis.

Whether these wheats have promise for breeding higher lysine will depend upon whether their high lysine values are real or only apparent. The effect of environment on lysine level is not known. A selected number of spring wheats from the World Collection were grown at four locations in the United States in 1967. A comparable number of winter wheats were seeded at three locations this fall. These will be analyzed to ascertain the magnitude of the environmental effect on level of lysine in wheat.

We are optimistic that wheats with superior levels of lysine will be found. Improved lysine level combined with high protein would constitute a major step in the improvement of the nutritional value of wheat.

IMPROVING WHEATS THROUGH BREEDING

Glenn S. Smith
Dean of Graduate School, North Dakota State University
Fargo, North Dakota

Introduction

Heredity versus environment. Improvement is a universal aspiration. It is good to improve. We all want to improve, our product, our personality, our profits, our progeny. The title implies that there are other ways to improve wheat than through breeding and, of course, there are. This will be the recurring theme of my remarks, the difference between hereditary and environmental influences on wheat. The breeder is successful if he can harness the hereditary influences, but at the same time he must recognize the influences, the variables if you will, which are not hereditary. He must recognize those factors which are external to the wheat plant (the environmental) and those from within (the hereditary). He must do this, not to bolster his ego as a breeder or a geneticist, but to achieve control over the new product.

Quality is complex. It has been well said in former meetings of this group that "Breadmaking is more complicated than steel-making or cracking oil." How true this is! We are not distilling off a product which has a specific boiling point, or a specific tensile strength with a given blend of two or three elements. We are dealing with a mixture of amino acids (tied together with several kinds of bonds), complex carbohydrates, lipid compounds, and minerals assembled by the microscopic physiologic processes of the growing plant. To this complex we add yeast, water, some more salt and sugar, and perhaps some fats and improving agents. Breadmaking is complicated, and it is no wonder we do not yet completely understand it. But until we completely understand, we cannot control quality, nor can we improve as fast as we should.

Texture for example. Let us take texture. What is more elementary in quality than endosperm texture? Texture is a basic factor in our wheat grades and classes. How about taking a quick examination? Here is a question. Are classes and subclasses controlled more by environmental or hereditary influences? Take subclasses first. Thatcher wheat can grade dark northern spring, or just northern spring. The difference is in texture, northern spring has more starchy kernels than dark northern. This, of course, is an environmental influence, because it is Thatcher in either case. The variables are rainfall, or perhaps nitrates in the soil. What about classes? It is obvious here that we are dealing primarily with hereditary differences, because we know that Thatcher, for example, is a hard wheat (it is vitreous) and Gaines is a soft wheat (it is starchy). If we are going to control, change, or improve texture, we must know whether it is controlled primarily by hereditary or environmental factors. We recognize at the same time that these factors are not clearly separated and distinct in their influences, but the hereditary controllers, we call them "genes," are always influenced and modified by environment. This is never more clearly illustrated than by grain texture. We have seen Thatcher so

starchy from being rained on that is looks like soft wheat. And we have seen soft wheats look very vitreous in certain seasons, or soils. So if we would understand, control, and improve wheat quality, we must distinguish environmental from hereditary variables.

Improving Disease and Agronomic Characters

Stem rust. The story of the improvement of North Dakota wheats is first a story of the stem rust problem. It begins in 1904 when we had a very severe stem rust epidemic. Our own Dr. Bolley and M. A. Carleton of the USDA had just returned from wheat exploration trips to Russia, and had independently brought back collections of durums. These were being tried in the spring wheat area, and in 1904 their stem rust resistance superiority to the Fife wheats and to Bluestem was revealed. Several of the durum varieties came through the rust epidemic in North Dakota with very little shriveling, whereas the older common wheats were severely injured. This put us in the durum wheat business and also led to more sophisticated testing and experiments with varieties. Then in 1916, stem rust struck again with devastating force. The economic shock was so severe that both the State and the USDA intensified their research efforts. Dr. L. R. Waldron was brought in from the Dickinson Experiment Station and appointed as the full-time wheat breeder. This time another wheat Bolley had brought over (named Kota) showed up as relatively resistant, whereas Marquis and other standard varieties were badly shrivelled and damaged. Dr. Waldron promptly crossed Marquis and Kota and the result was Ceres wheat, which was somewhat more rust resistant than Marquis, more drought resistant, and perhaps equal to Marquis in baking quality. (Figure 1 shows the 1934 Ceres wheat acreage).

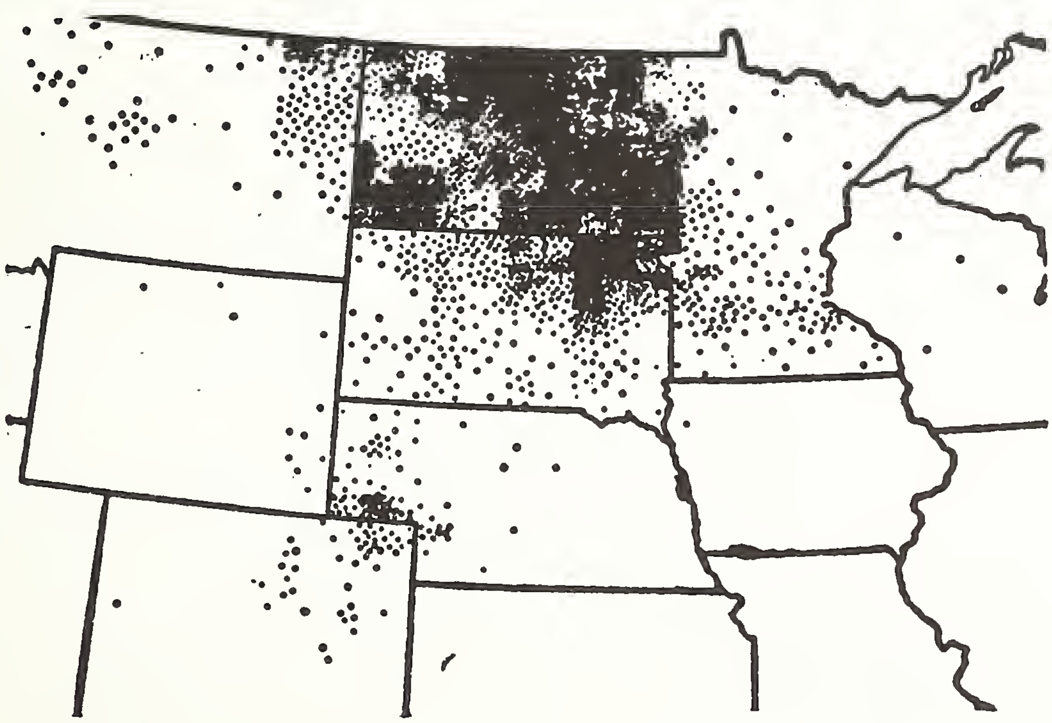


Figure 1. Planted acreage of Ceres wheat (4,453,487 acres), 1934.

Again in 1935, stem rust struck the spring wheat region with sudden and destructive effect, and Ceres was knocked out of the picture, because the prevailing variety of stem rust had changed. A new rust, identified as race 56 became predominant. Fortunately the breeders of Minnesota had already produced Thatcher, a double cross with Marquis, which carried resistance from Iumillo durum and Kanred winter wheat. North Dakota and South Dakota breeders and the USDA had been hybridizing with Hope wheat, a cross between Marquis and Emmer, so other wheats resistant to race 56 soon were available, Rival and Pilot in 1939 and Mida in 1944. (The acreage of Mida in 1945 is shown in Figure 2). Because of the heavy rust losses,

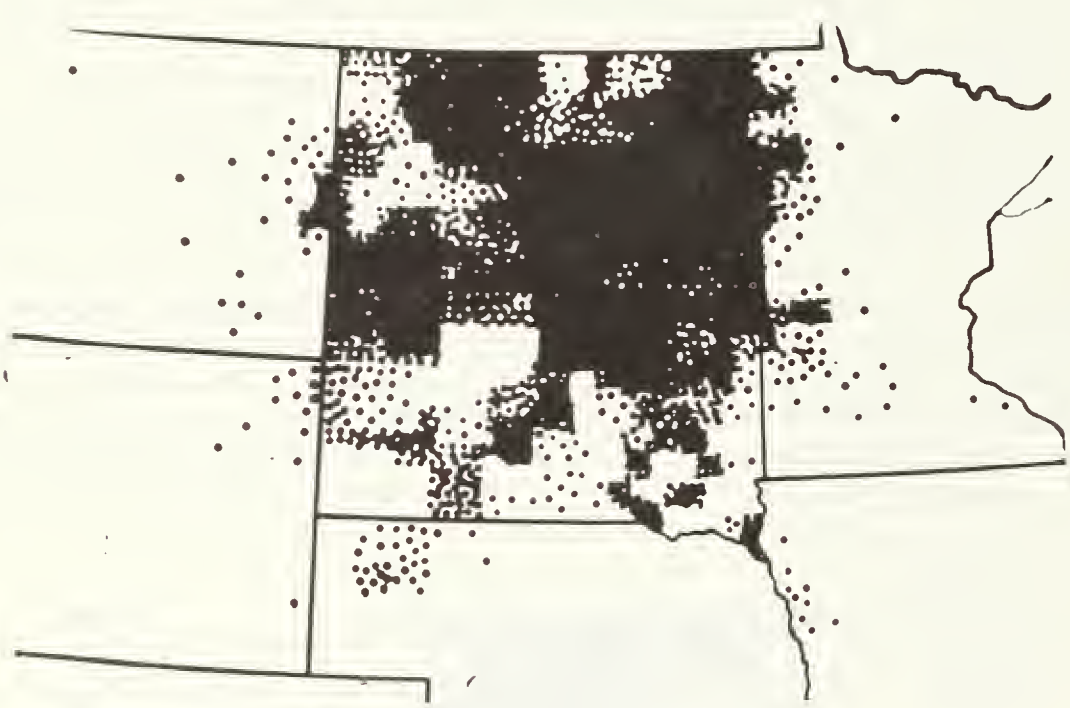


Figure 2. Planted acreage of Mida wheat (5,554,156 acres), 1949.

growers and the trade supported increased expenditures for the research of wheat breeders, pathologists, and cereal chemists. By this time the importance as well as the complexity of quality was becoming better recognized.

Stem rust struck again in 1950 and in 1953, and 1954, this time with special intensity on the durum varieties in the form of race 15B, a race already identified as dangerous and one to which no commercial variety in the United States was resistant. Since then Selkirk and other 15B resistant wheats and durums have been coming out at an accelerating pace, because the 15B scare again led to greatly increased support for the wheat research program. It seems that out of adversity has come research support. It is very doubtful if the wheat scientists would have been given nearly as much support without the stimulus of the four or five stem rust debacles in the past half century.

Other characters. Fortunately, wheat researchers have been able to give attention to other hazards than stem rust, and improvements have resulted. Table 1 shows the superiority of Justin over Marquis in a number

Table 1.--Marquis and Justin compared, progress 1915-1965

Character	Marquis	Justin
Straw	weak	strong
Shattering	easy	tough
Leaf rust	90%	20%
Stem rust	80%	5%
Yield (bu./acre)	10-30	20-40
Protein	12.5%	14%
Loaf volume	700	800
Farinograph	5	7
Sedimentation	55	70

of important characters. Today, Chris, Justin, and Manitou not only carry excellent stem rust resistance, but they are superior in earliness, straw strength, shattering, and even in quality to the bread wheats of an earlier day. Chris and Manitou are superior to Justin also in leaf rust resistance and in yield.

The durum wheat breeding program began seriously in 1929, with attempts to improve the tall weak straw of rust susceptible Mindum and Kubanka. We used Vernal emmer, a red-kerneled, tough threshing wheat relative to cross with Mindum as a source of rust resistance. By selection for rust resistance and quality, and then backcrossing twice to Mindum, we produced Carleton and Stewart, our first forward steps. In 1941, a new series of crosses with a variety named Heiti was begun to add earliness and shorter straw to the durums. Figure 3 shows a cross between Ld 216, a Carleton derivative, and Ld 240, a short Heiti derivative. The result was Nugget, a short early durum with yielding capacity equal to Carleton. Nugget also illustrates transgressive segregation, that is variability beyond either parent. In this case, Nugget goes beyond either parent for macaroni color. We feel that an alert plant breeder can often capitalize on transgressive segregation. This is a particularly valuable technic if you wish to create a new intensity of a desired character. The deep yellow color of Nugget contrasts sharply with the reddish color of macaroni made from Vernal emmer, and with the previous standard, but more pale yellow, of Mindum.

About the time we got short straw, earliness, and deeper yellow macaroni color going in the durum wheat program, 15B stem rust came along and we had to intensify our stem rust efforts again. This resulted in a rapid-fire sequence of durum varieties, until now the most recent, Leeds,

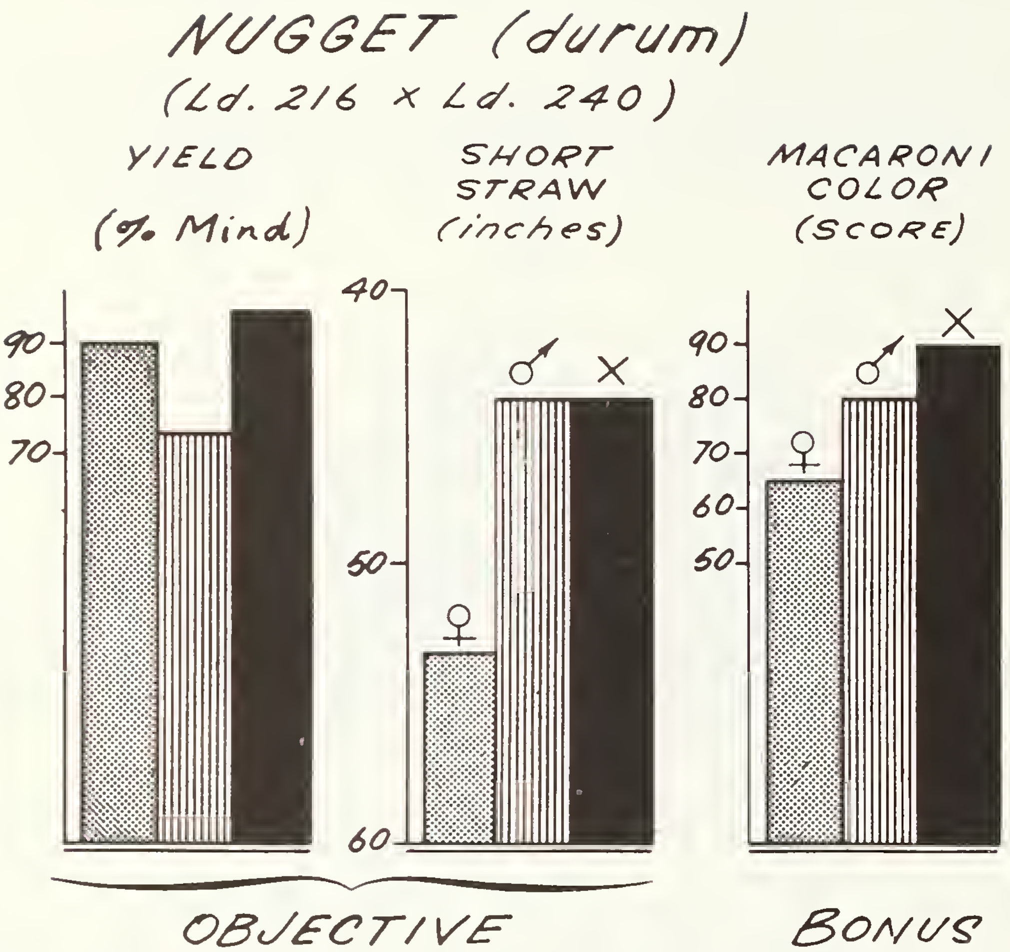


Figure 3. Transgressive segregation for quality (macaroni color) in Nugget durum.

presents a very bright picture, varietywise both to the producer and the processor. Leeds is superior in stem rust resistance, earlier, shorter, stronger, better quality, and significantly better in yield than the old varieties.

Looking at both the present bread wheats and the present durum wheats, it would be difficult to exaggerate the dollar return for each tax penny invested in wheat research since Dr. Waldron made his first crosses, 50 years ago.

In detailing the progress in improved varieties, I am referring, of course, largely to the improvement in the heredity of the varieties available to the grower and to the trade. This does not mean that significant advances in controlling the environment were not being made during the same period. They were. The Soils men have refined fertilizer and tillage practices; the Pathologists have given us chemical control of bunt (have you heard of any threshing machines blowing up lately?); and the Entomologists have reduced the inroads of insects. Some of these improvements leave the breeder more time to concentrate on improving yielding capacity or quality. (How nice it would be if we did not have to breed for rust resistance!) One advantage of hereditary improvements is that once bred into a variety, the advantage is relatively permanent. A variety with built-in yielding capacity will give more bushels each year, without expenditure for fertilizer. Of course the good farmer will use fertilizer too, if the straw is strong enough to stand up.

Simple versus complex heredity. How are these hereditary improvements accomplished? I shall not go into a detailed explanation here of the choice of parents, making the cross, selecting and testing hundreds of new wheats derived from each new cross, and the problems of deriving dependable pure lines from segregating populations. I want to speak rather of the primary problem in recombining any two desirable characters from two parents into a single progeny. The primary problem is, "how complicated is the heredity?" We classify any character as either "simple" or "complex." A simple character is one which is controlled by one or just a few genes, whereas a complex character, of course, is controlled by many. Varietal breeding is highly empirical. Most agronomic characters have not been analyzed in genetic studies to the point where one could say, for example, that earliness is controlled by two genes, and test weight by 15. However, the breeder must plan his program as if he did know approximately how many genes control the characters involved in each cross. A reasonably accurate estimate of the complexity of each character by which the parents differ is essential. This is why the plant breeder is very interested in genetic studies, and why most breeders carry along some genetic studies paralleling their so-called practical work.

During the past few years, I have been privileged to work with 10 graduate students. Eight won their M.S. and two their Ph.D. degrees, and all chose problems involving some facet of wheat genetics. Each student has studied the inheritance of several different characters. Some studied taxonomic features of the plant such as leaf sheath barbs, awns, or auricle hairs; some studied kernel features, such as brush, pericarp color, or endosperm texture; some studied plant growth features such as winter or spring habit, or height, and some studied the inheritance of disease reactions. Altogether we have studied 18 different characters, and our best judgment is that we have identified 43 different genes.

A good example of a single factor pair is John Longwell's study of the inheritance of kernel brush length. The two parents presented a clear-cut contrast in this character. Many durum varieties have a short brush, about 0.1 millimeter, but the other parent is more typical of the emmers

with their long brush, 5 to 10 times as long. In spite of this wide difference, there was a rather clear indication of a single gene difference, as shown in Table 2, a 1:3 ratio in F_2, and a 1:2:1 ratio in F_3. This

Table 2.--Kernel brush length

F_2 brush classes	F_3 brush classes: Long	Segregating	Short	Total
Short	0	1	63	64
Long	63	106	1	170
Total observed	63	107	64	234
Calculated	58.5	117	58.8	234

(Longwell) P = 0.05 to 0.30

is an example of a simply inherited character; it could not be any simpler; length of kernel brush was controlled by a single pair of genes, one derived from each parent.

Let us take an example slightly more complicated. Dr. F. E. LeGrand studied a character which was controlled by two pairs of genes, winter habit. He did not start out to study winter habit, but this simply illustrates what interesting sidelights develop with genetic studies. We had a cross between a semidwarf wheat, ND 259 and Conley, a variety of normal height. Both were of spring type, that is they headed from spring planting, and the F_1 also was a spring type. Our first clue to winter habit derivatives appeared in the greenhouse when we took heading date on the F_2 plants from September planting. Conley headed in about 60 days, and ND 259 in about 75 days. Most of the F_2 progeny headed within this range, but there was a significant fraction which headed 2-3 weeks later than the late parent. And then, out of the 176 total plants, 13 remained grassy and refused to head until late in January, 140 to 150 days after they were planted. Significantly, 13 is not far from 1/16 of 176, the total F_2 population. When LeGrand planted seed from these 13 late plants in the field next year, they looked "grassy." Conventional winter wheats behave very much like this when sown here in the spring. They tiller out profusely and refuse to head. He vernalized these plants and this broke their dormancy, convincing us further that we had produced a winter wheat by crossing two spring types. The occurence of 1 winter type plant in 16 F_2's suggested the hypothesis that we were dealing with a two factor difference. Since both parents were of spring type, it was evident that each parent carried a recessive factor pair for winter habit, but this never showed up in the presence of even one dominant gene for spring. In other words, winter habit was controlled by the double recessive, and reflected the absence of any genes for spring type.

So here is another example of a simply inherited character, this time a two-factor difference. After having solved this genetic puzzle, we can predict with confidence that an F_2 population of 25 or 30 plants from this cross is almost certain to give us at least one winter type plant, if this is the object of our program, because the odds are 1:15. Instead of working in the dark, we have some assurances on the size of population required for this particular character.

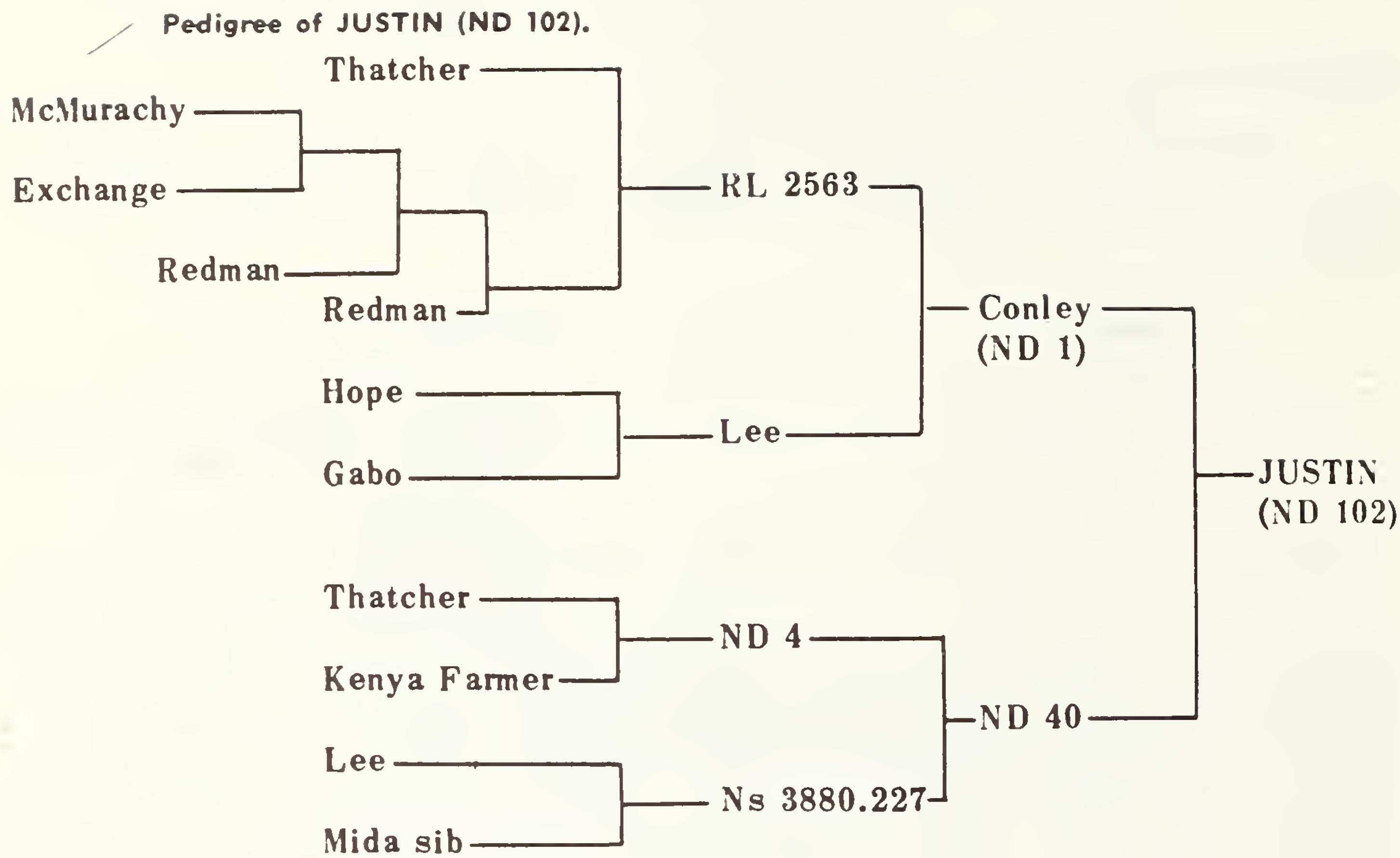
Notice here that the two-factor character is four times as difficult to recover as the single-factor character. We are dealing here with a geometric progression and a little arithmetic will reveal that when you get into characters controlled by several genes, the size of the population required to recover a single desired pure type increases geometrically, 4, 16, 64, 256, 1,024 etc., the latter for only five pairs of genes.

Improving Quality Characters

The odds. Unfortunately, many of the characters needed in an improved wheat are controlled by more than five pairs of genes. Take quality for example. Dr. Finney has listed the several quality characteristics in a bread wheat:

Milling	Baking
bolting	flour protein
hardness	mixing requirement
flour yield	mixing tolerance
ash	oxidation requirement
wheat protein	dough handling
	absorption
	loaf volume
	crumb, grain, and color

Here we have a possibility of not five genes but 13. If the parents differed in each of the 13 quality characteristics, and if each character were controlled by a single gene pair, it would require an F_2 population of 67,108,864 plants to recover a single plant with the desired gene combination, and do you suppose we could either find or identify this one plant if we could grow that many? Actually, of course, an exotic rust-resistant wheat from Kenya, even though it is starchy, low in protein, weak in mixing tolerance and loaf volume, is probably not inferior in all 13 characters. And probably protein in the flour is controlled by the same genes as protein in the wheat; and perhaps there is a genetic association between mixing requirement and mixing tolerance, and even with loaf volume. If so, this reduces the contrasting numbers of genes involved, but immediately I must point out that not one of these individual quality desiderata has been shown to be controlled by a single genetic factor. It is very exciting to the plant breeder to see studies such as those of Welsh and of Morris and others which suggest that a single chromosome, or even a single gene may carry a large influence on bread quality. However, although single genes may cause striking effects, surely most quality characters are relatively complex, genetically. So it is obvious that we are not going to recover acceptable quality with the first cross to exotic varieties. This explains why our pedigrees are complicated. Here is the pedigree of Justin (Figure 4). The earlier ND numbers were just steps along the road, picking up important agronomic and disease characters, and as many as possible of the necessary quality genes, until eventually we got something acceptable. We have had similar experience in breeding for quality in the durums.



PARENTAGE OF JUSTIN

Figure 4. Pedigree of Justin HRS.

<u>One test is not enough</u>. Our difficulties in breeding desired quality characteristics into new wheats are not just statistical. They also involve my original theme, sorting the environmental from the genetic influences. Suppose the cereal chemist could run one mixogram each on 100 new wheats, and say "This is it. You have five which are excellent, 70 mediocre, and 25 are horrible, and they will rank in the same order next year." But he cannot say this. Even though the mixogram data show perhaps the highest heritabilities of any quality character, we know there is a strong possibility that not all the same five will be excellent next year, because of superimposed environmental influences. So I repeat, we must constantly seek to distinguish the environmental and the hereditary.

Everyone wants a simple quick test. The baker wants a "quick test" because he has limited flour storage capacity, and because lots of loaves come out of an automated process before the need for a change can be recognized. The plant breeder wants a simple quick test because he needs an early indication of quality on a new wheat when seed stocks are very limited.

Dr. Charles Saunders of Canada, producer of Marquis wheat, recognized the basic problem 60 years ago when he suggested that what the breeder needs is a simple test which will indicate the baking strength from a single wheat plant, and leave some seed for planting. Dr. Saunders did more than complain. He used the "chewing test" to detect the high quality of that famous wheat, Marquis. As he said, "It required some patience and a fairly good set of teeth, but these two attributes may be considered essential to all breeders of wheat." Today we have come a long way from the "chewing test," but we still do not have a microtest for 10 kernels or even 10 grams. And even the mixogram is not a bake, useful as it is, so we must continue to build up our basic knowledge of the complex factors relating to wheat quality.

North Dakota "Team Studies." At North Dakota, the cereal chemists have been pursuing their basic studies, as well as running thousands of screening tests for the breeders; and the breeders have been pursuing genetic studies as well as producing thousands of new wheats for the chemists to test. But, down through the years, we have made a point on several occasions to get together as a team on special studies which seemed important in this whole problem of understanding the component influences on wheat quality.

An early study was published in the 1932 Journal of Agricultural Research by Waldron and Mangels. They studied the variability in certain quality characters in two different series of wheats grown in the same 4 years, 1927 to 1930, on the same soil, Fargo clay. One series was the single variety, Ceres, grown in the rotation and fertility plots with varying history of previous cropping, tillage, and fertilizers. (Here the variability was environmental.) The other series was a group of about 70 different wheats grown each year in a single nursery experiment (variable heredity). The quality characters studied were protein, absorption, loaf volume, and loaf weight. The variables of soil and climate thus were held constant in this study. To make a long story short, they found that heredity caused the most variability in absorption, loaf volume, and loaf weight, whereas environment caused more variability in protein content. I thought this was a very interesting early study, resulting from the team approach.

One year (1941) we were getting many inquiries as to how much injury sprouting caused to durum quality. So we built some trays and sprouted some durum to three different stages of sprouting, and studied the influence on macaroni quality of blending various proportions. We found that if the germ had barely broken through, little damage resulted, but that if the plumule were longer than the kernel, a small percentage in the blend would severely reduce the quality of the macaroni produced. Sprouting, of course, is environmental.

For many years we wondered what caused macaroni to turn from the opaque putty color of the dough to the translucent clear color of the extruded product. A cooperative miscroscopic examination of the macaroni revealed that the dough mix contained countless microscopic bubbles, incorporated by the mixer, and that these coalesced under the high pressures of extrusion into fewer and larger bubbles, giving a translucent product. Under

controlled pressures we were able to show that time and pressure controlled the size and number of the air bubbles. Now, the air is excluded from the macaronic mix. This, of course, was entirely an environmental effect.

Other team studies between our departments have shown that starchy endosperm is a simply inherited genetic character which has an important bearing on flour volume, strictly a hereditary effect.

I consider the last variety we released, Justin, an important team effort, because over a period of several years the two departments followed the strong mixing and baking characteristics of one parent, Conley, in many different crosses and hundreds of different progenies, until we were able to recover it in Justin, which for the 3 years before 1967 was the leading wheat on North Dakota farms. Here environment and heredity were intimately interwoven.

We boast further that our station has never released a wheat that was a problem variety qualitywise, and this of course is the result of an on-going team effort.

Conclusion

The wheat breeder is highly dependent upon the cereal chemist in his efforts to breed more productive and better quality wheats for whatever use the world requires. He has help from many other disciplines, plant pathologists, soils people, entomologists, physiologists, even engineers now to build him growth chambers. Traditionally, many of the breeder's critical observations have been made on the plant, visually. But he is especially conscious of the importance of a well-developed science of wheat quality, because these evaluations relating to utilization cannot be made by a quick look at the wheat plant, or the grain.

Wheat research should be geared to the complexity of the problem, not just to the economic difficulty or the cost-price squeeze of the moment. Otherwise wheat utilization will fall behind in competition, and will not make the maximum contribution it should. Wheat improvement is a challenge to the best minds available anywhere, and the reward is the satisfaction of helping to solve some of the most critical problems of our age.

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INDICATION OF WHEAT FLOUR QUALITY BY CHANGES OF FLOUR PROTEINS UNDER VARIOUS CONDITIONS

C. C. Tsen
American Institute of Baking
Chicago, Illinois 60611

A number of speakers of this Conference have talked about wheat protein. The emphasis on protein is understandable and logical. Nutritionally, wheat protein is our major daily protein source. Its importance has been repeatedly pointed out by various speakers in this conference. Wheat protein also plays an important role in dough development, carbon dioxide retention, and bread structure stability in the breadmaking process. Breadmaking is the oldest and most important process for wheat utilization. In fact, for centuries the unique viscoelastic properties of wheat protein have been utilized for breadmaking. But in spite of the recent advances in cereal chemistry and baking technology, we are still not able to define exactly the term flour quality for breadmaking.

Baking and farinographic tests for flour quality. The most accurate test for flour quality is still the baking test. Figure 1 shows the baking results obtained with six different flours. Except the commercial flour (H.R.S.), the others were milled on a laboratory Buhler mill under the same conditioning and milling conditions. Then they were tested by the Remix method (1). You can see the marked differences in loaf volume and appearance among bread samples prepared from these flours. The texture and grain of these breads also show a significant variation. These results are brought out here to illustrate that flours do vary in their qualities for breadmaking.

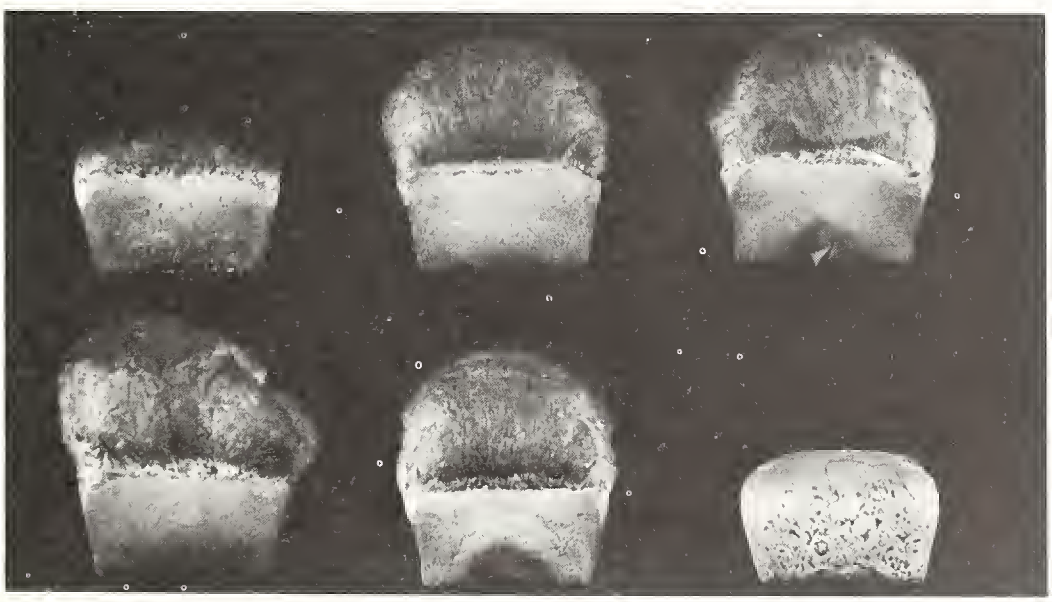

Figure 1. Bread loaves prepared from different flours: P.P. = Prairie Pride, TH. = Thatcher, PEM. = Pembina, MIN. = Minnesota II-54-29, H.R.S. = Hard Red Spring Wheat Flour, W.W. = White Winter.

In addition to the baking test, farinographic tests are commonly used to test flour quality by measuring the rheological properties of flour-water dough. The rheological properties of dough are important because dough occupies an important position between flour and bread. Dough properties reflect the quality of the flour from which it is made. At the same time its properties also determine the quality of bread which can be made from it.

Figure 2 presents farinograms of flour-water doughs prepared from these six flours. You can see that white winter, a soft wheat flour, and Prairie Pride, a hard spring wheat flour, produce doughs that develop and break down rapidly when mixed in the farinograph. They are generally called weak flours. Whereas flours such as Pembina and Minnesota II-54-29, whose doughs develop slowly and tolerate prolonged mixing, are usually regarded as very strong flours. Between the above extremes are strong flours such as Thatcher and the commercial flours.

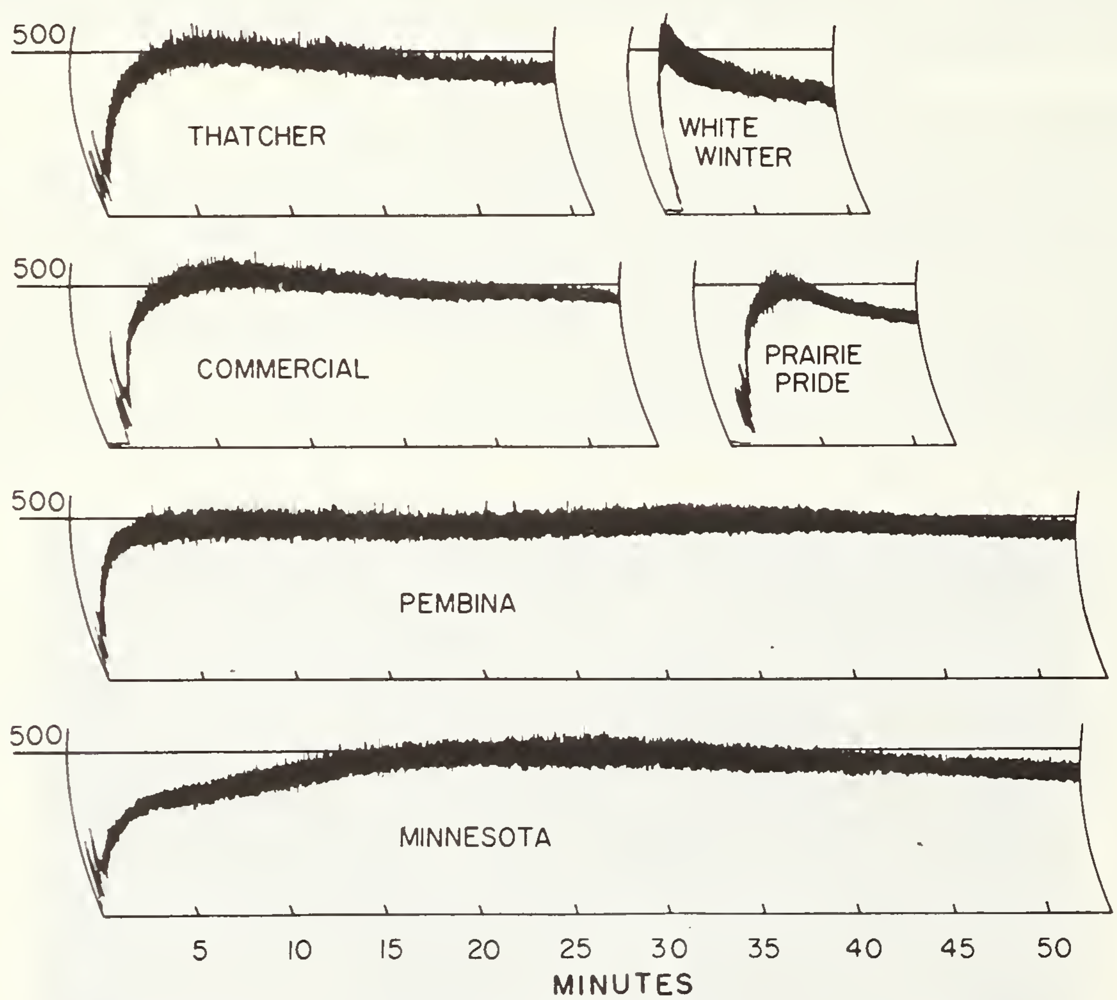

Figure 2. Farinograms of flour-water doughs.

Mixing properties concerning dough development and breakdown are important parameters in the assessment of flour quality. Their importance has become more significant than ever before with the introduction of continuous mix processes in which dough development is achieved primarily by high-speed mixing. In other words, the flour used in the continuous mix process should be strong enough to stand the mixing.

Now, how do we relate the differences in baking quality and mixing properties to the chemical composition of flours? This certainly is one of the most challenging problems for cereal chemists.

Protein content and quality. The search for a chemical basis of flour quality has been active over the past 50 years, but the problem is still not completely solved. The protein content of flour is regarded as a good indication of the quality of flour. However, it is well known that various flours of nearly equal protein contents often differ markedly in both mixing properties and baking performance. The difference is presumably due to the variation in protein quality of different flours. Since the protein is composed of amino acids, at first it was thought that the amino acid composition of flours might differ from one another. But recent studies of Tkachuk (2), Hepburn and Bradley (3), and Simmonds (4) all show that poor and good baking quality flours of similar protein contents differ very little in their amino acid compositions. Even flours from different classes of wheats have almost the same amino acid composition. Furthermore recent work at Chorleywood has shown that amino acid analyses of rye, barley, oat, and corn flours have an overall similarity to one another (5). Then the difference in protein quality is likely due to the variation in the quantitative distribution of protein components in different flours or the structural difference of proteins in various flours.

Quantitative distribution of components in the protein extract of flour. In this section, the distribution of protein components will be discussed. Our recent studies with gel filtration of flour protein show that the distribution of protein components is different for different flours (6). For example, we used dilute acetic acid to extract proteins from a soft wheat flour and a hard wheat flour with a Waring Blendor. The extraction was repeated four times to obtain about 95 percent of the total protein from the flour. The extract was used for gel filtration on a column of Bio-Gel 150. The results, given in Figure 3, show that from the extract are separated four major UV absorbing components, I, II, III, and IV, representing primarily glutenin, gliadin, albumin, and globulin, and soluble nonprotein. The classification and distribution of these components, to a large extent, agree with those of Wright, Brown, and Bell (7).

The results, given in Figure 3, present two important features. First, proportionally, the extract of hard wheat flour contains more large size proteins (components I and II, 79.4% of the total protein) than does that of soft wheat flour (69.7%).

Second, the ratio of glutenin to gliadin, component I to II, in the gluten fraction is 2.54 for the hard wheat flour and 2.40 for the soft wheat flour. In other words, as far as the distribution of protein components in the extract is concerned, the hard wheat flour has proportionally more glutenin than gliadin in the gluten fraction and less soluble proteins than does the soft wheat flour. Gluten is, of course, related to the baking quality of flour, and so is the soluble protein, as shown by Pence et al. (8,9). It is, therefore, conceivable that the quantitative distribution of protein components

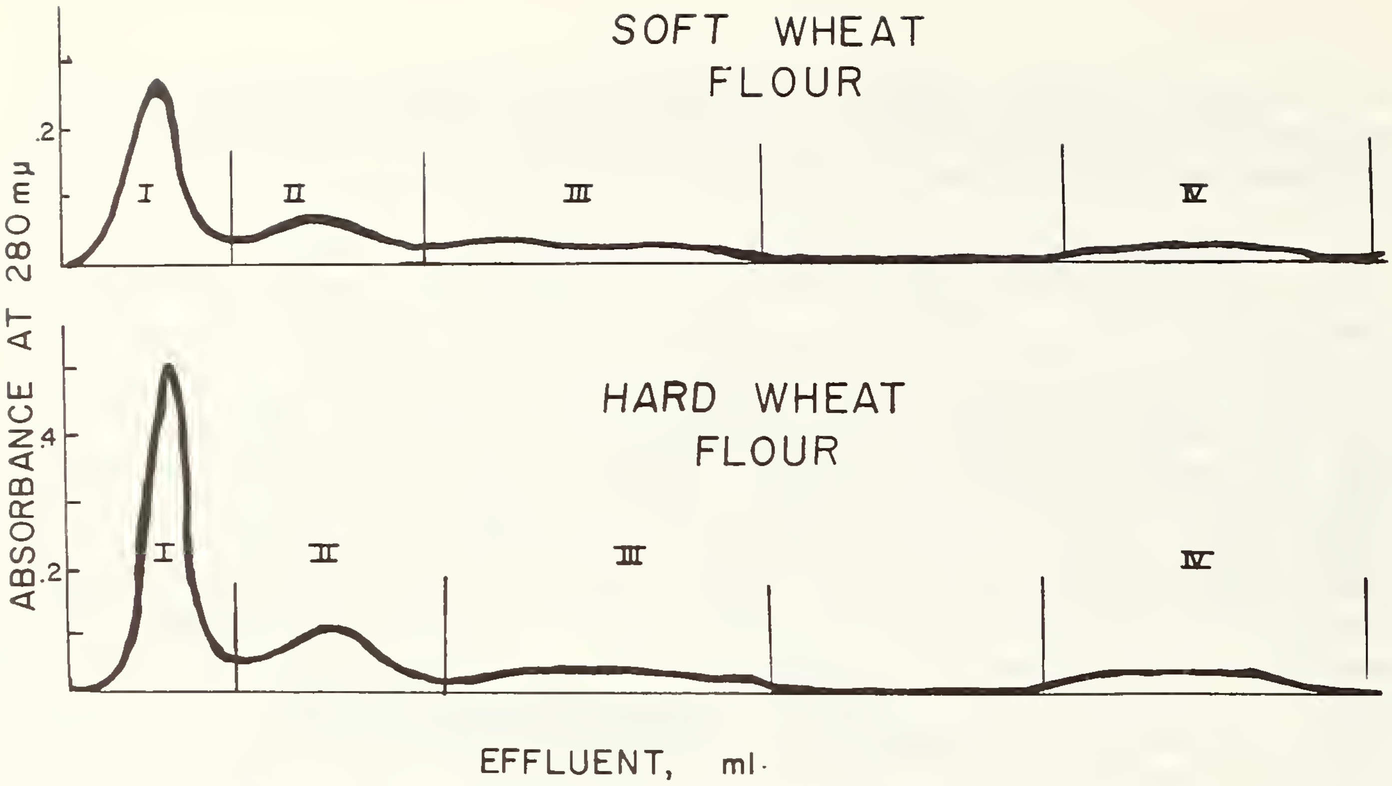

Figure 3. Protein distributions in the extracts of a commercial wheat flour (H.R.S.) and a white winter wheat flour (S.W.W.).

in flour protein may give a better indication of protein quality and flour quality than other measures that have been proposed. Additional work is in progress at the American Institute of Baking to include more flours and to do more analyses in order to have more conclusive data about the flour protein distribution.

Changes of flour proteins with mixing. In this and following sections, the main discussion will be on "The Changes of Flour Proteins with Mixing."

The mixing properties of dough largely depend on the viscoelastic properties of flour proteins. The difference in mixing properties could mean the difference in changes of flour proteins with mixing. The examination of changes of flour proteins with mixing is probably a direct and practical way to evaluate protein quality and also flour quality. Research has been started along this line. Results are promising.

Mecham and coworkers (10,11) observed that when protein was extracted with dilute acetic acid from a flour and also from its flour-water doughs, the amount of protein extracted was least from the flour and increased with dough mixing. Rates of increase were different for flours of different mixing properties. We have extended their work further to study changes in molecular size distribution of protein components in the extracts and relate their changes to mixing properties of flour and flour quality (12).

The procedure of our study is outlined as follows: Flour and water were mixed in a farinograph. After mixing for a required period, a dough

sample was taken. It was freeze-dried and ground in a micro-Wiley mill. A 2.5-g. sample was extracted with 30 ml. 0.05 N acetic acid on a shaker for 15 minutes in a cold room. The mixture was then centrifuged at 30,000 gravity and 4° C. for 15 minutes. The supernatant was referred to as the acetic acid extract. The extract was fractionated by gel filtration on a column of Bio-Gel 150 and eluted by 0.002 N sodium acetate. The optical density of the effluent was monitored by an automatic UV analyzer.

The separation results, given in Figure 4, show that component I increases with mixing for 3, 6.5, 15.5, and 31 minutes, while the other components do not change significantly. These results are confirmed by using gluten instead of flour and by using aluminum lactate instead of sodium acetate as the eluting agent. Furthermore, mixing at a higher speed can intensify the increase in component I. The increase in component I is apparently not at the expense of other soluble components or gliadins. It must result from the disaggregation of large protein particles (aggregates) during mixing. In other words, not all flour proteins can be extracted by dilute acetic acid. But with mixing, more protein can be extracted, resulting in the increase in component I.

Relation of changes in protein components to flour quality. As mentioned before, some weak flours develop and break down rapidly, while strong flours develop slowly and tolerate the mixing. Now let us relate these mixing properties to the changes of protein components during mixing. Figure 5 shows the effect of mixing on the protein distribution of the extracts of white winter and Thatcher flours. First, the extract of white winter flour contains a higher proportion of component I than that of Thatcher flour. This difference is also observed between other soft and hard wheat flours including Genesee, Talbot, Richmond, and Pembina, and Minnesota wheat flours.

The difference in extractability with acetic acid indicates that the size of large protein particles or aggregates of soft wheat flours may be smaller than that of the hard wheat flours or that the structure of large protein particles of soft wheat flours may be weaker than that of the hard wheat flours. This finding supports the suggestion of Smith and Mullen that alpha-glutenins of weak and strong flours might be different in their molecular size (13,14). It also agrees with Pomeranz's observation that poor and good breadmaking flours differ in their protein dispersibilities in 3 M urea (15).

Second, component I of white winter flour increases faster than that of Thatcher flour during 3.5 minutes of mixing. The difference suggests again that the structure of large protein particles of the soft wheat flour is weaker than that of the hard wheat flour. This indicates the bonding of large protein particles in a weak flour is not as strong as that in a strong flour.

The last figure shows the comparative data for Pembina and Prairie Pride flours and their doughs. These flours are taken as examples of very strong and weak varieties of the same class of wheat (Hard Red Spring). You can see that there are no marked differences in the distribution of components

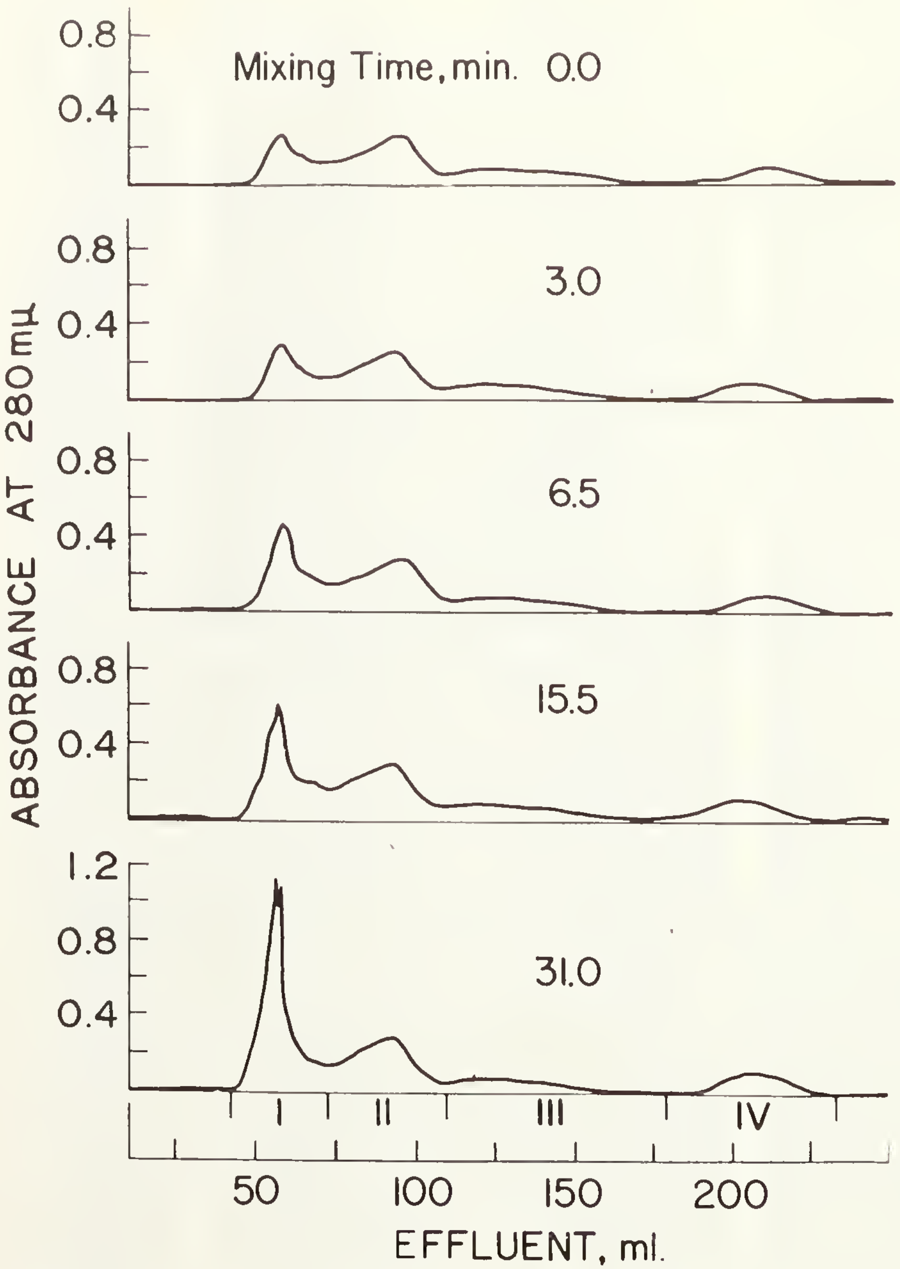

Figure 4. Gel filtration of acetic acid extracts from flour and flour-water doughs mixed for various periods.

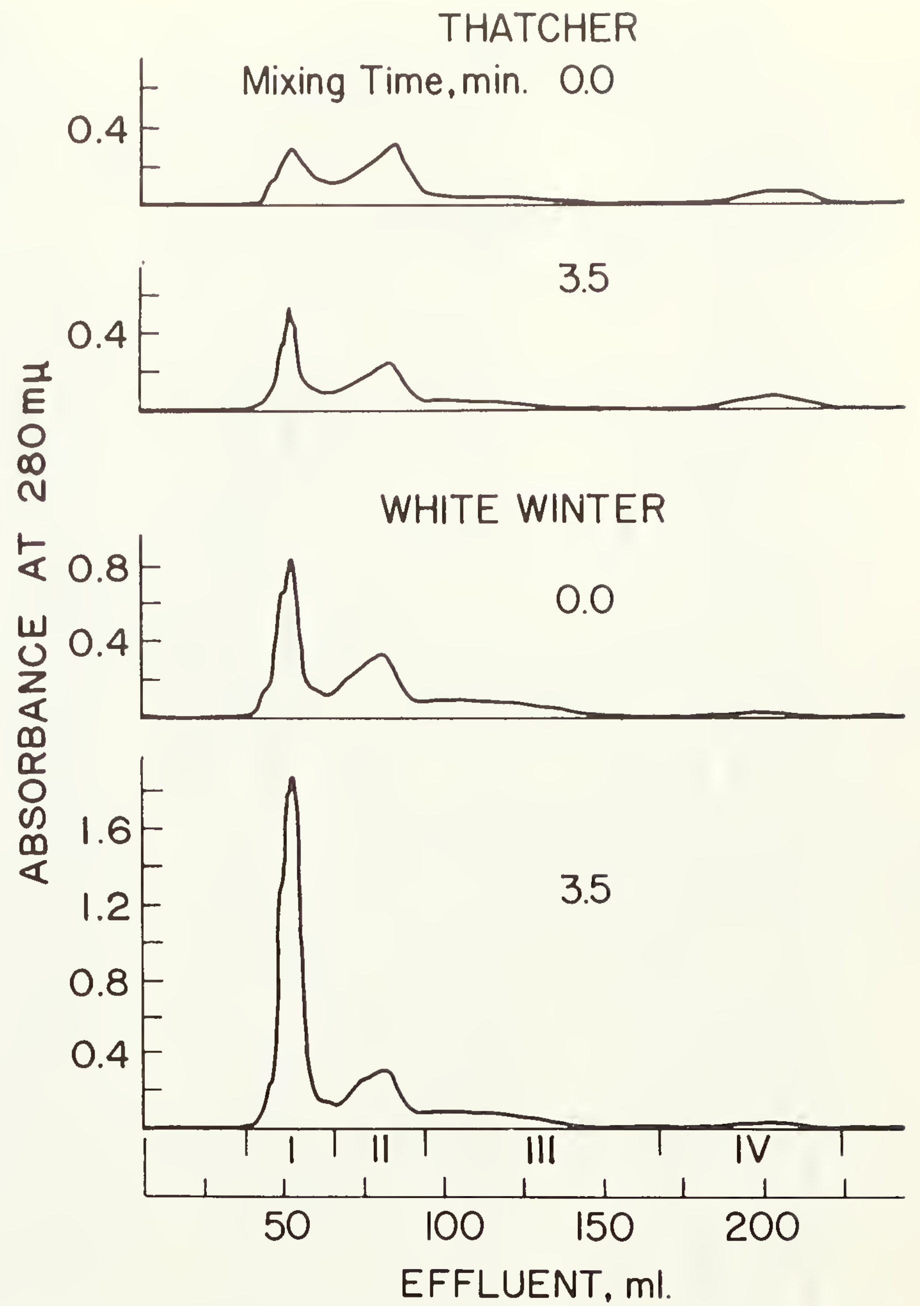

Figure 5. Elution curves for protein components of Thatcher and white winter wheat flours and their doughs extracted with acetic acid.

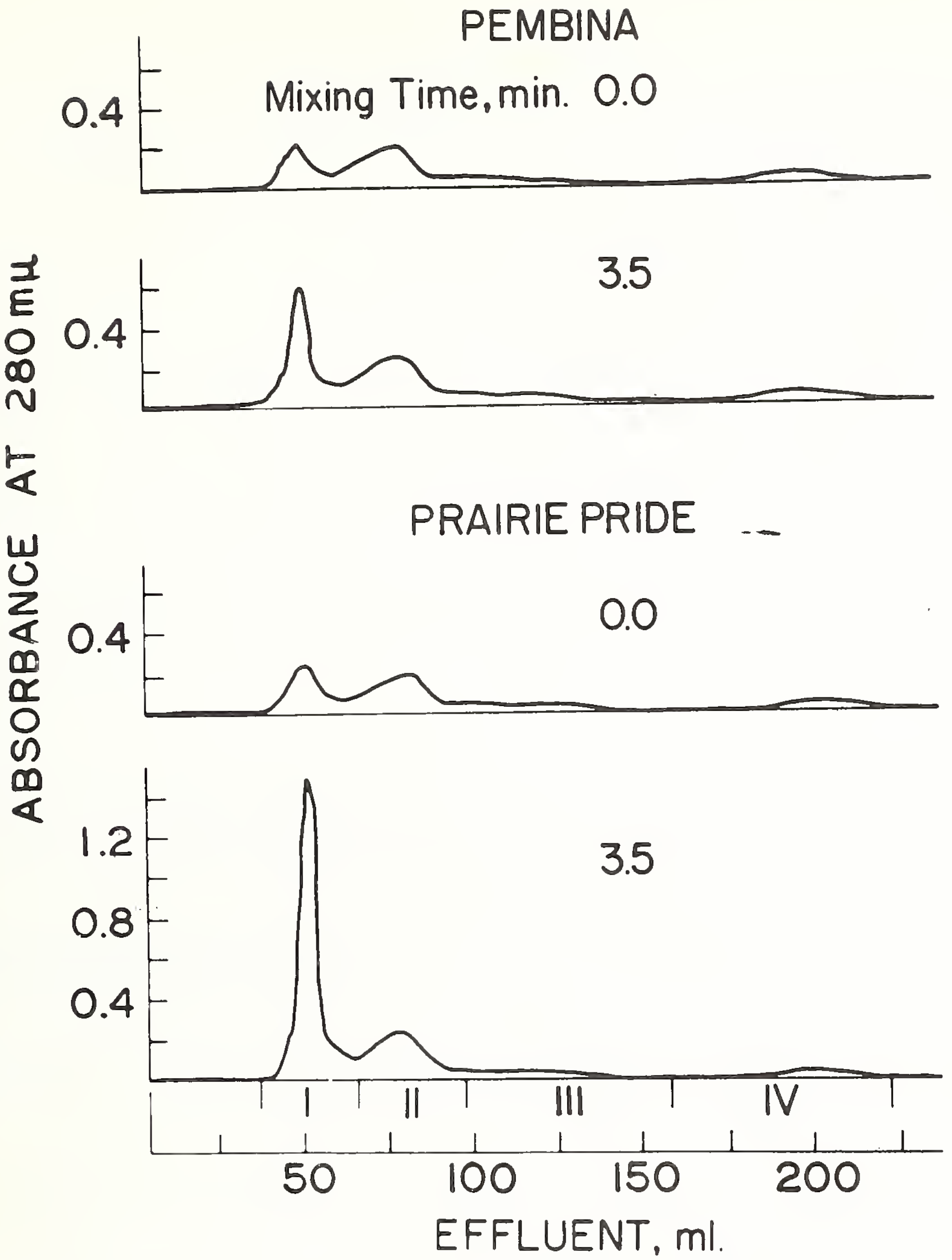

Figure 6. Elution curves for protein components of Pembina and Prairie Pride wheat flours and their doughs extracted with acetic acid.

in the extracts of these two flours. However, during mixing, the amount of component I increases much faster in the Prairie Pride flour than in the Pembina flour. Results for Minnesota, Thatcher, and the commercial flours confirm the above finding that the rate of increase in the amount of component I with mixing decreases as the strength (dough development time) of the flour increases. In conclusion, all these findings show that the difference in the distribution of protein components and in the change of protein components with mixing could serve a useful indication for protein quality and provide a new angle for testing flour quality.

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REVIEW OF WHEAT PROTEINS

Joseph S. Wall
Head, Chemical Reactions and Structure Investigations
Northern Regional Research Laboratory, Agricultural Research Service
U.S. Department of Agriculture
Peoria, Illinois

The proteins of wheat flour contribute greatly to the rheological properties of flour doughs and to the baking quality of the flour. The manner in which flour proteins participate in dough formation is readily evident in scanning electron microscopy views shown in Figure 1. These

Wheat Flour **Flour Dough**

Figure 1. Scanning electron micrographs of flour and dough particles. (From Aranyi and Hawrylewicz (1)).

highly magnified pictures of flour and dough particles were taken by Miss C. Aranyi and Dr. Hawrylewicz (1) in studies sponsored by the Western Regional Laboratory. Unlike conventional electron microscopy, these views show the surface of the particles. On the left the electron micrograph shows the starch particles and adhering pieces of protein. On the right are particles of dough produced after hydration of the flour and kneading. The protein in the dough is distributed as a coherent film, coating and connecting starch granules. Its elasticity and adhesiveness are responsible for the unique behavior of the dough as a plastic mass.

Gluten insolubility, cohesiveness, and elasticity have proved a challenge to the protein chemist. Indeed, 10 years ago a review of knowledge of wheat gluten proteins would have been an easy chore. Little was known about their chemistry. In the ensuing period new solvents for their solution, new techniques for their separation and structural analyses, and more important, new concepts of their structure and behavior were developed. As a result, work on gluten protein has accelerated and progress has been rapid.

Current research has proceeded in several directions. Since wheat flour contains a large number of different proteins, it has been necessary to separate and isolate the individual proteins to permit their detailed study. Purification of proteins permits analysis of their amino acid composition and allows even more detailed determination of amino acid sequence. Because the chains of amino acids in proteins are often chemically linked and folded into definite structures, physical measurements of size and shape are important to an understanding of their properties. The elasticity and cohesive character of hydrated gluten proteins causes us to inquire into the forces that contribute to their associations and interactions with themselves and other constituents of flour. Since action of some improving agents may be centered on the proteins of wheat flour, we are exploring the effect of oxidizing and reducing agents on gluten proteins. And finally, we would like to establish whether the baking characteristics of flour from different wheat varieties are related to genetic changes in their proteins.

Wheat flour proteins are a broad and an extensive field for investigation, and many different approaches are being pursued in many laboratories. In the time allotted me, I will be able to describe only a few of the results from our Laboratory.

Separation and characterization of gliadin proteins. The major protein fractions of wheat flour are, of course, gliadin and glutenin. These proteins are similar in amino acid content and are insoluble in neutral aqueous solutions. However, their molecular size and physical properties are quite different. In earlier reports before this group, evidence was presented that the nature of the disulfide bonds in these proteins was responsible for their differences as shown in Figure 2. Disulfide bonds are formed by oxidation of the sulfhydryl groups present in the amino acid cysteine. Gliadin consists of several different proteins whose disulfide bonds link different parts of the same chain of amino acids. In contrast, some of the disulfide bonds of glutenin link different chains together. As a result, glutenin molecules are much larger than those of gliadin and have additional differences in physical properties. Breaking the disulfide bonds by the reaction of reducing agents converts both gliadin and glutenin to the basic chains of amino acids of which they are composed.

The traditional method of separating gliadin and glutenin is based on the greater solubility of gliadin in 70 percent ethanol. Unfortunately, by this technique fractionation is not complete and the products obtained are not free of contaminants. To separate gliadin and glutenin from each other, better gel filtration chromatography was used as shown in Figure 3 (2). This procedure separates the protein on the basis of differences in their

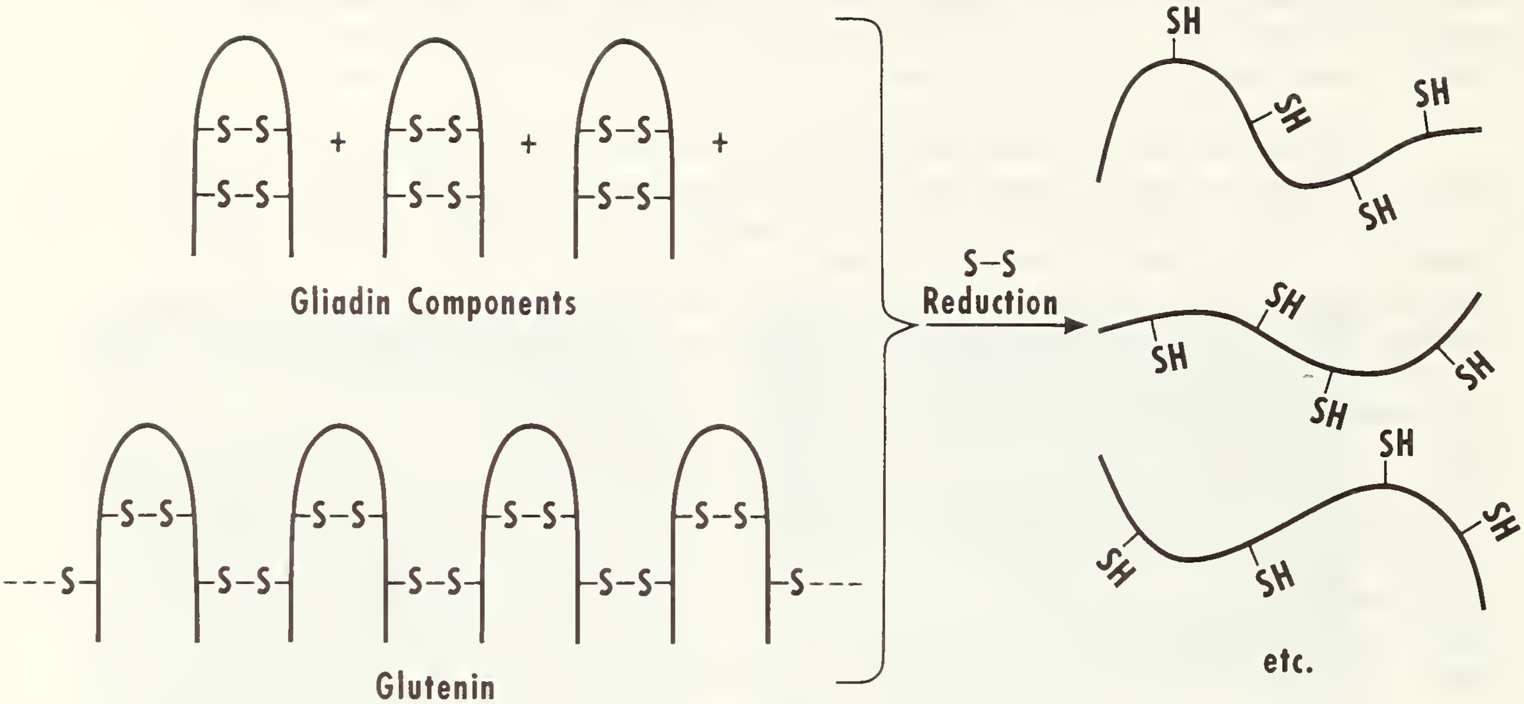

Figure 2. Position of disulfide bonds in gliadin and glutenin and the effect of reducing them on molecular structures.

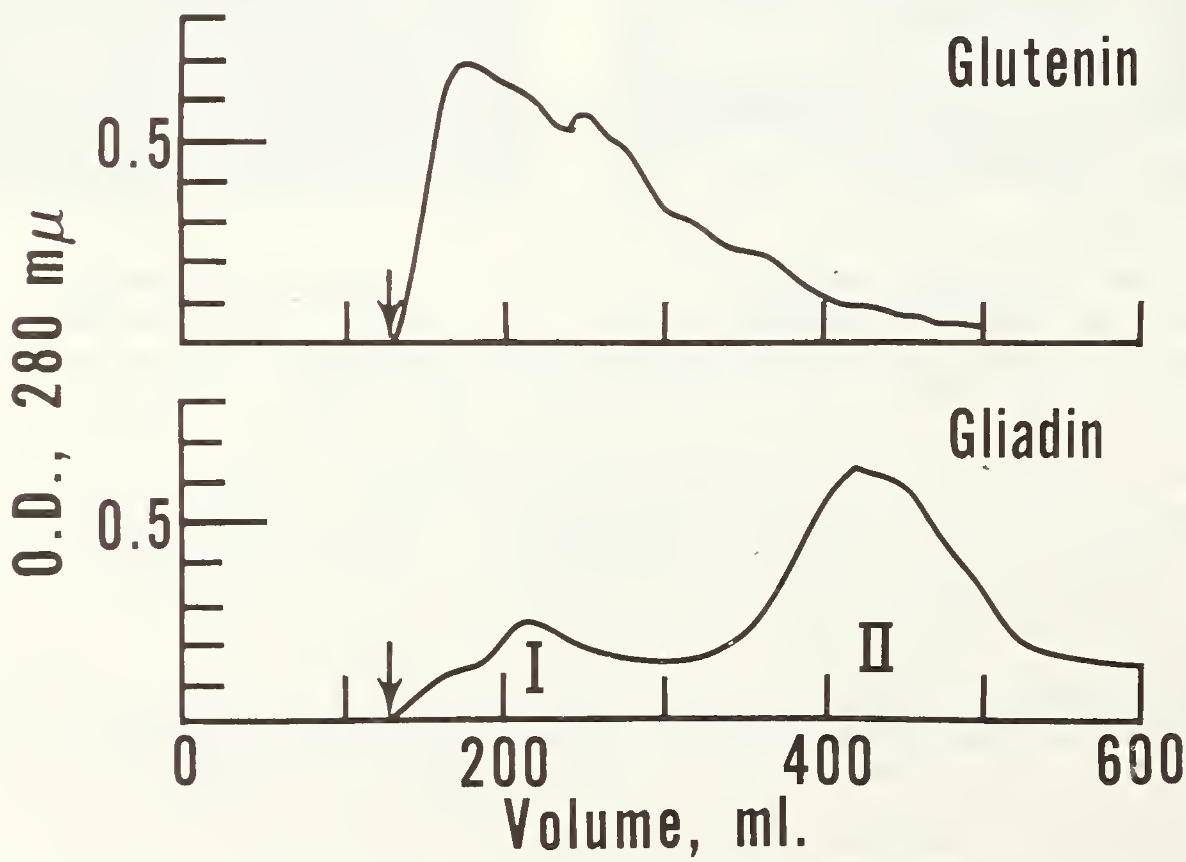

Figure 3. Gel filtration chromatography of glutenin and gliadin on Bio-Gel P-300 in 8 M urea. Column 3.8 X 155 cm.

molecular size. The proteins are filtered through a column of a hydrated crosslinked resin or polysaccharide. Small molecules enter into the pore of the gel particles and are thereby retarded in their migration through the column. The larger molecules which cannot penetrate the gel particles are eluted earlier. When glutenin is placed on a column of crosslinked polyacrylamide, it is eliminated from the column in the early fractions of effluent. This position of elution is in agreement with the large molecular weight established by ultracentrifuge analysis for this material. The wide pattern obtained for glutenin indicates that it is not of a uniform molecular weight. In contrast, most of the gliadin comes off in later fractions in a fairly symmetrical peak. Some high molecular weight material is eluted and separated from most of the gliadin earlier.

By a similar chromatographic procedure we can obtain pure preparations of gliadins free of high molecular weight material. The molecular weights of this purified gliadin and the solvent extracted classical gliadin are compared in Table 1 (3). Note that the higher molecular weight of the whole

Table 1.--Molecular weight of high molecular weight gliadin, classical gliadin, and purified gliadin before and after disulfide bond-cleavage[1/]

Item	Before disulfide cleavage, M_w	After disulfide cleavage, M_w
High molecular weight fraction	125,600	36,800
Classical gliadin	42,900	26,200
Purified gliadin	26,900	22,300

[1/] Determined in 8 M urea-0.1 M formic acid.

gliadin from solvent fractionation, 43,000, is attributable to the presence of a high molecular weight protein. The purified gliadin is fairly uniform in molecular weight, around 27,000 in this solvent. The heavier material has a molecular weight of 125,000. When whole gliadin is treated with reducing agents so as to cleave its disulfide bonds, its molecular weight drops. In contrast, the purified gliadin shows little drop in molecular weight after reduction. The high molecular weight fraction separated also by gel filtration chromatography diminishes markedly in molecular weight when its disulfides are cleaved. Through amino acid analyses and studies of other properties, this heavier material was found to be more closely akin to glutenin than gliadin. The maintenance of molecular weight by purified gliadin upon reduction supports the concept that gliadin contains only intramolecular disulfide bonds.

Since a preparation of gliadin that was fairly uniform in physical properties was available, we set about to fractionate it further into its constituent proteins. For this purpose, we developed a new ion-exchange chromatographic procedure (4). The protein was absorbed onto a column of sulfoethyl cellulose (SEC), a cellulose to which charged groups were chemically added. Because of their differences in charges in the acid solvent employed, the proteins were bound with differing tenacity to the modified cellulose. The proteins were then eluted from the column at different rates by washing it with a solvent containing an increasing concentration of sodium

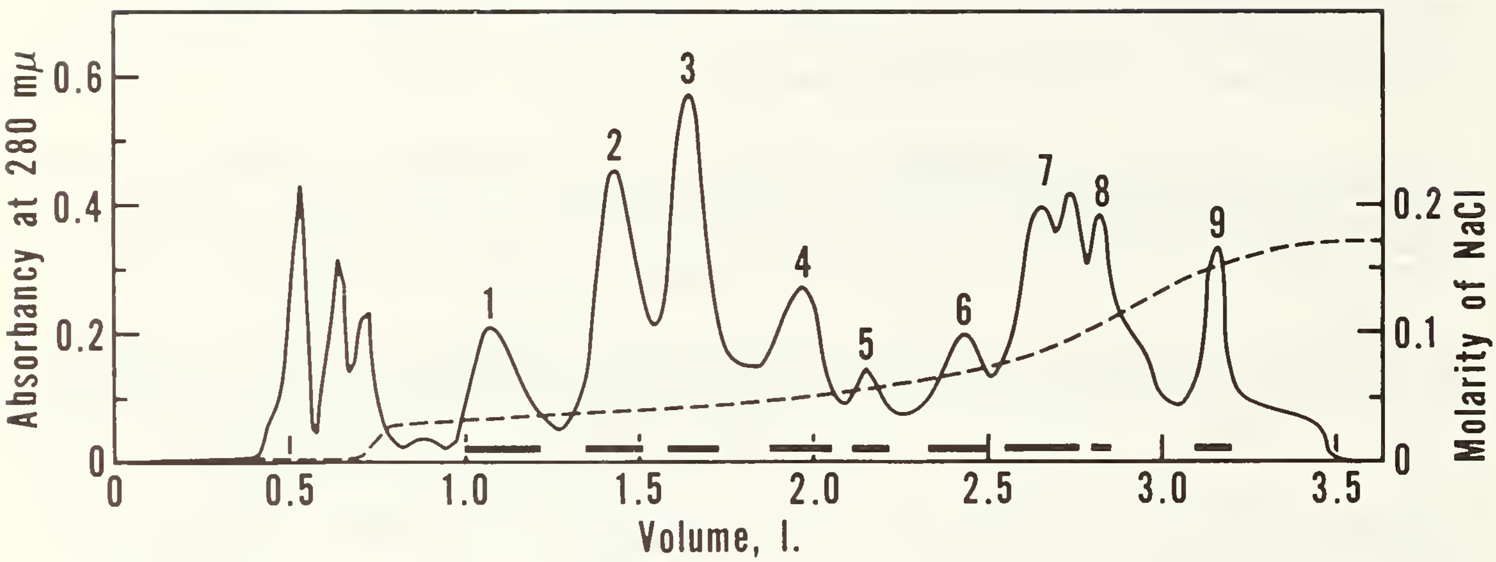

Figure 4. Chromatographic separation of gliadin on sulfoethyl cellulose (SEC) column 3.9 X 50 cm. in pH 2.1 HCl acetic acid buffer containing 2 M dimethylformamide.

chloride. The elution pattern is shown on Figure 4. The height of the peaks indicates the amount of protein present in the eluted fractions. The dashed line represents the change in salt content in the eluting solvent. In Figure 5 are illustrated starch-gel electrophoretic patterns of the components of each peak. Some of the peaks contain at least several proteins. There are many more gliadin proteins than one would anticipate from starch gel patterns alone.

Figure 6 illustrates how we have separated some very closely related proteins that we previously thought were identical. When peaks 1, 2, and 3 of the chromatographic separation of Figure 4 are fractionated further by gel filtration chromatography, a single component is obtained from each peak that has a mobility on gel electrophoresis corresponding to gamma-gliadin. These components are three distinct proteins. Amino acid analyses of each of these purified proteins show slight differences between them. Gamma 1 contained no lysine, whereas gammas 2 and 3 each had one residue of lysine. Differences in glutamic acid and tyrosine contents were also noted. These small differences in composition may result in marked changes in physical and nutritional properties. We are now trying to investigate the detailed structure of these purified proteins. We expect that learning the location

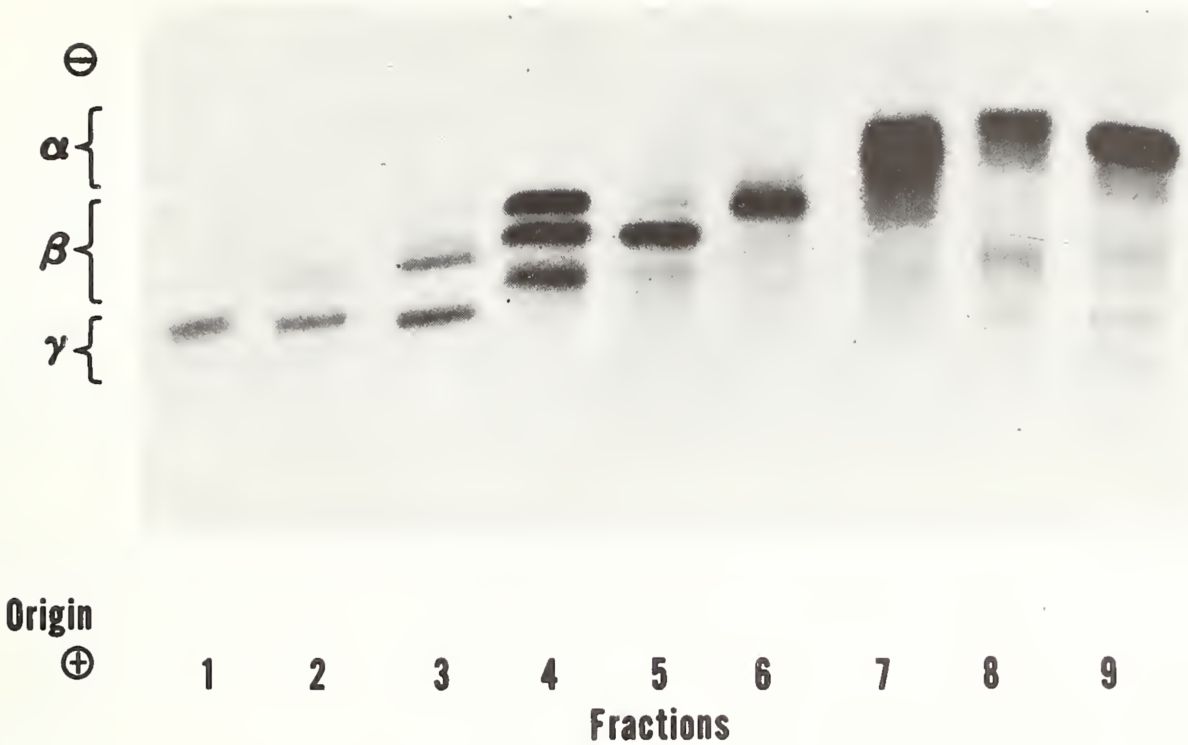

Figure 5. Starch gel electrophoretic patterns of gliadin fractions from chromatography of wheat gliadin on SEC. Fractions are those represented by solid lines under peaks in Figure 4.

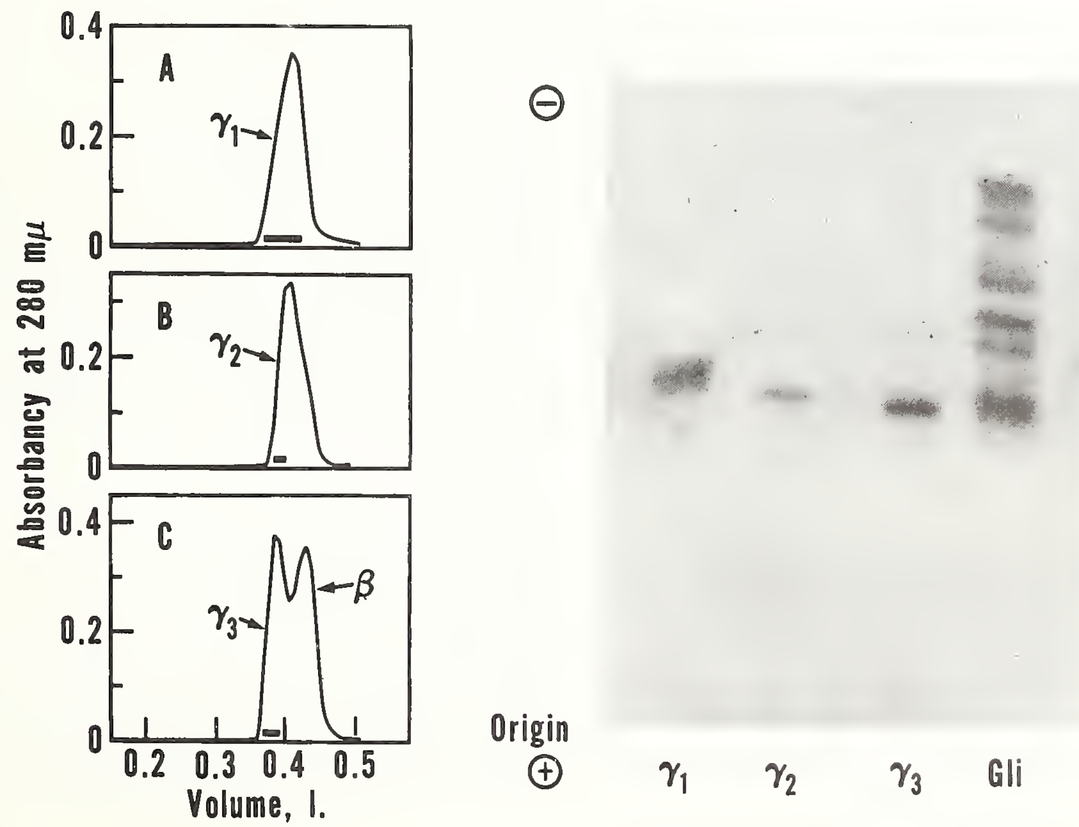

Figure 6. Purification of gamma gliadins from SEC column fractions by gel filtration on Sephadex C-50 in 0.05 M acetic acid solvent.

of disulfide and other functional groups in the polypeptide chain will help us to understand better the behavior of these proteins.

Reduction and reoxidation of glutenin. Separated glutenin and gliadin exhibit different viscoelastic properties when each is hydrated. Glutenin forms a tougher, more elastic mass than does gliadin. It, therefore, makes a greater contribution to the elasticity and cohesiveness of the flour dough. The higher molecular weight of the glutenin resulting from intermolecular disulfide bonds between polypeptide chains is probably responsible for these properties. In some new commercial processes, preliminary addition of reducing and oxidizing agents hastens the development of doughs during mixing. Undoubtedly such a procedure involves altering the disulfide bonds of the glutenin and gliadin. Our studies on the reduction and reoxidation of glutenin may provide information as to the chemistry of this process.

The effect of varying amounts of reducing agents on the cleavage of glutenin disulfide bonds is illustrated in Figure 7. The reaction was

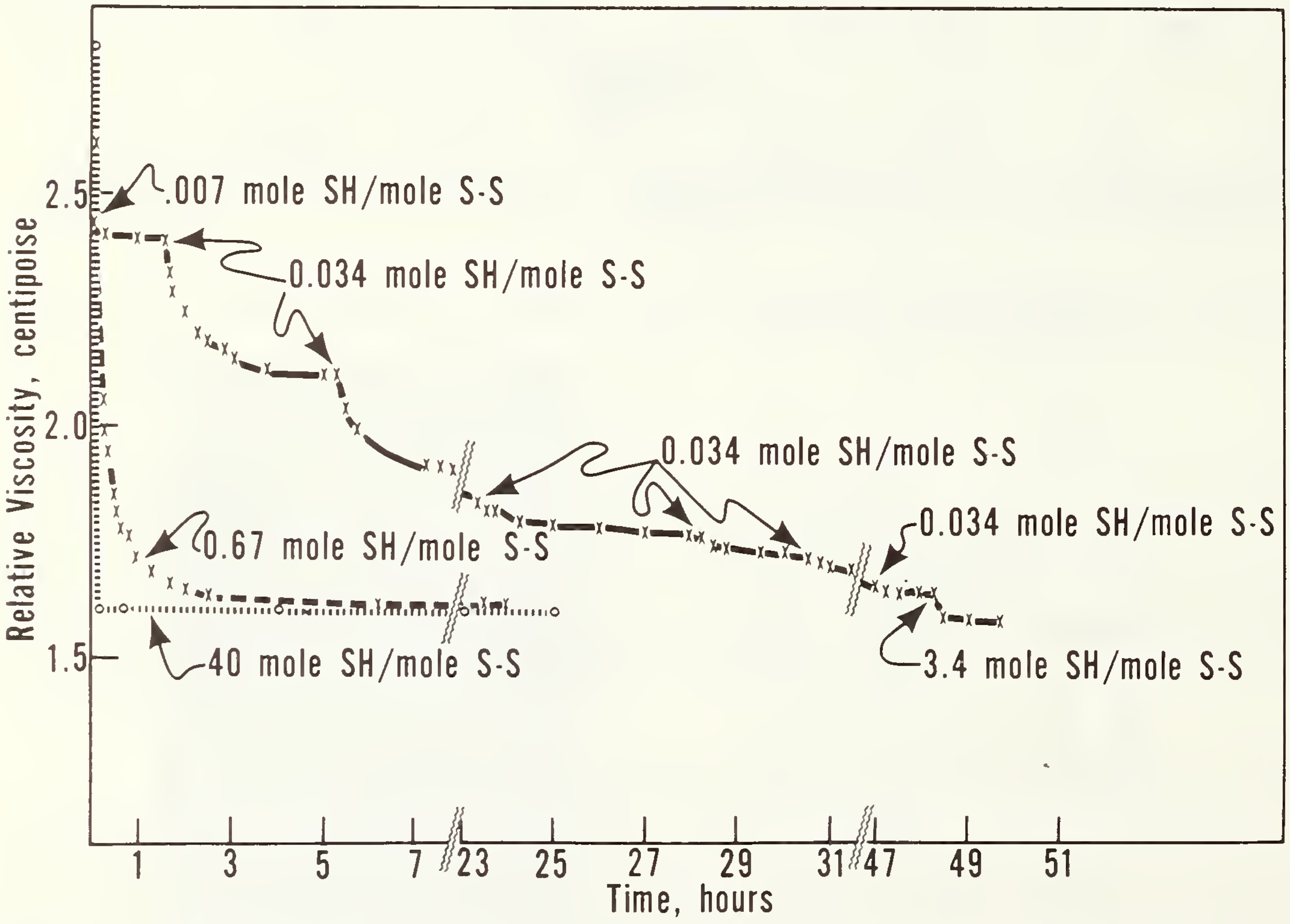

Figure 7. Changes in viscosity of glutenin during reduction with mercaptoethanol for a 1 percent solution of glutenin in 1 M Tris-8 M urea buffer, pH 7.0.

carried out in 8 M urea to insure glutenin solubility and access of reducing agents to all disulfide bonds. The addition of a very small amount of the

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reducing agent, thioethanol, caused a rapid large drop in viscosity, which we attribute to the breaking of disulfide bonds. Subsequent equal additions of the thiol reagent produced further decrease in viscosity but at increasingly slower rates. A ratio of 0.67 moles of mercaptoethanol per gluten disulfide group results in maximum decrease in viscosity. This minimum viscosity probably signifies complete disruption of glutenin into its constituent amino acid chains. These findings suggest that not all glutenin disulfides are involved in interchain linkages that the interchain disulfides are more susceptible to scission than those within the chain.

We are exploring the nature of the products resulting when glutenin disulfide bonds are cleaved by reducing agents. In Figure 8 is shown a gel

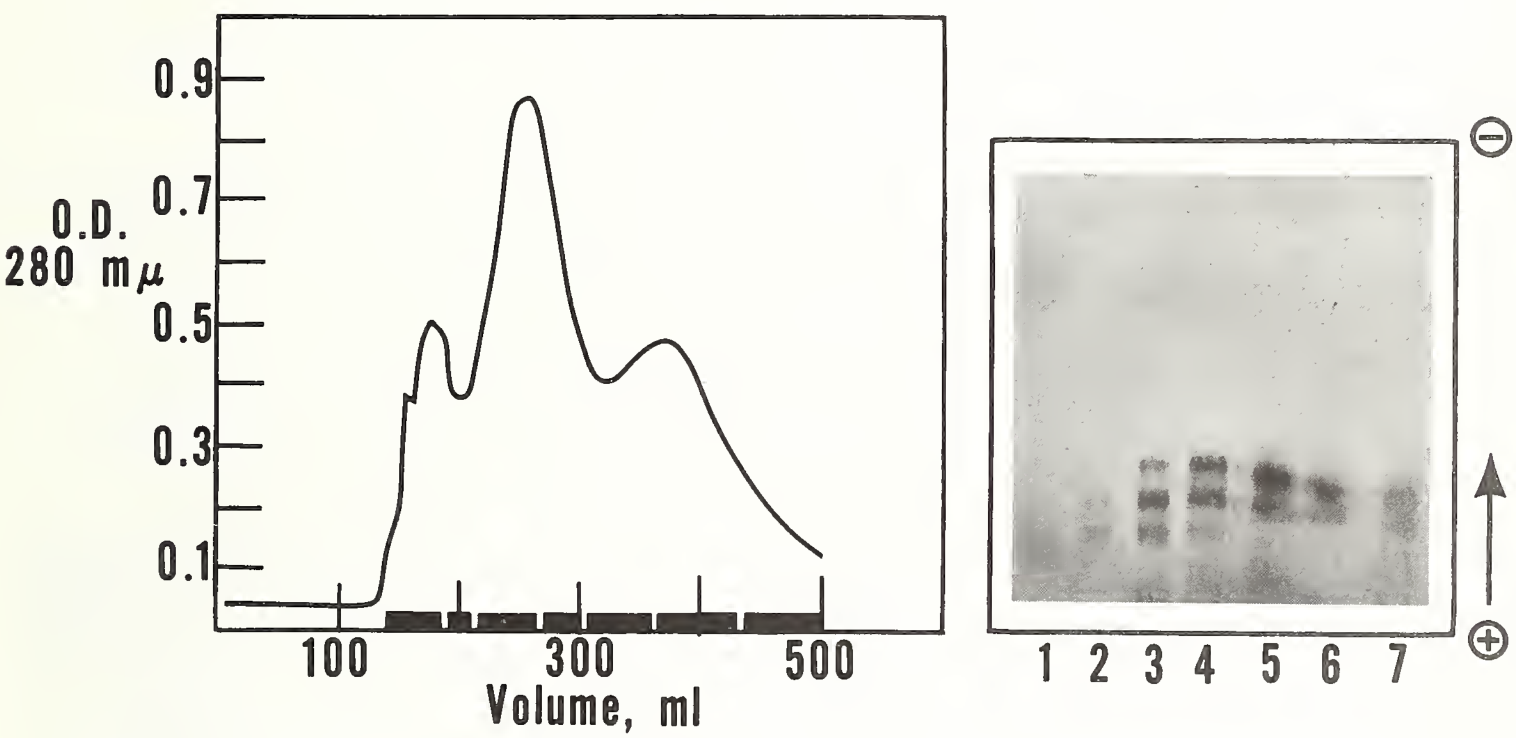

Figure 8. Gel filtration chromatography of reduced and alkylated glutenin on Bio-Gel P-300 column.

filtration chromatographic separation of the proteins contained in reduced alkylated glutenin. After the protein was reduced to liberate sulfhydryl groups, these groups were reacted with an alkylating agent, acrylonitrile, to block their subsequent oxidation. The chromatographic separation indicates that glutenin is not cleaved to components of uniform properties. Since the separation was conducted in 8 M urea, the results are probably not due to aggregation. Also, analysis of the reduced alkylated materials indicated that there were no disulfides left uncleaved. The protein fragments may vary in size or shape.

When the reduced protein is not alkylated to protect sulfhydryl groups, air or such other oxidizing agents as bromate will cause reoxidation of the sulfhydryl groups to yield new disulfide bonds. By reoxidizing the glutenin under various conditions, we have explored the structural details that contribute to the unique elastic properties of the protein (5). The properties of these various chemically altered glutenins are compared to native protein in Table 2. The native glutenin has a high intrinsic viscosity

Table 2.--Properties of native, reduced, and reoxidized glutenins

Glutenin	Sedimentation coefficient, $S_{20,w}$ 1/	Intrinsic viscosity (dl/g) (pH 3.1. aluminum lactate)	Behavior of hydrated product
Native	4.34	0.77	Cohesive elastic
Reduced			
Alkylated	1.70	0.23	Noncohesive
Reoxidized at 0.1%, pH 3.5	2.36	0.20	Noncohesive
Reoxidized at 5.0%, pH 3.5	1.52 7.82	0.45	Cohesive elastic
Reoxidized in suspension (about 10%), pH 3.5	Insoluble		Cohesive nonelastic

1/ Determined in 6 M guanidine hydrochloride-0.1 M HCl corrected to water by the factor $S_{20,w}/S_{20}$ = 2.70.

in solution and when the solid is hydrated, it becomes an elastic-cohesive mass. Upon reduction and alkylation of glutenin, the viscosity diminishes and the protein loses its elastic-cohesive character. When the protein is reoxidized in dilute solution so that the different polypeptide chains are distant from each other, the resulting product contains primarily intramolecular disulfide bonds. Like the reduced material, the viscosity of this product is low and it does not behave as an elastomer when hydrated. However, when glutenin is reoxidized at 5 percent protein concentration, the molecules are sufficiently close so that a large number of intermolecular disulfide linkages are formed. This material has increased viscosity and is elastic and cohesive when hydrated. It resembles native glutenin in its physical properties. If reoxidation occurs in suspension so that the proximity of sulfhydryls is so great as to favor intermolecular disulfide bonds exclusively, the molecules which result are extremely high in molecular weight and extensively crosslinked. The product is very tough and inelastic. Thus glutenin possesses desirable properties when the appropriate degree of interchain and intrachain disulfide bonds are formed and the molecule is of suitable size.

In flour doughs, rheological properties are the summation of the interaction of many components. To understand how gliadin and glutenin proteins interact with each other, we have investigated their viscosities in concentrated solution. We have also examined the physical behavior of films. On the basis of these studies, we can begin to understand why glutenin molecules have a greater tendency to associate than do gliadin molecules. How

the molecules in hydrated masses of gliadin and glutenin may be depicted is shown diagrammatically in Figure 9. The surfaces of these molecules contain

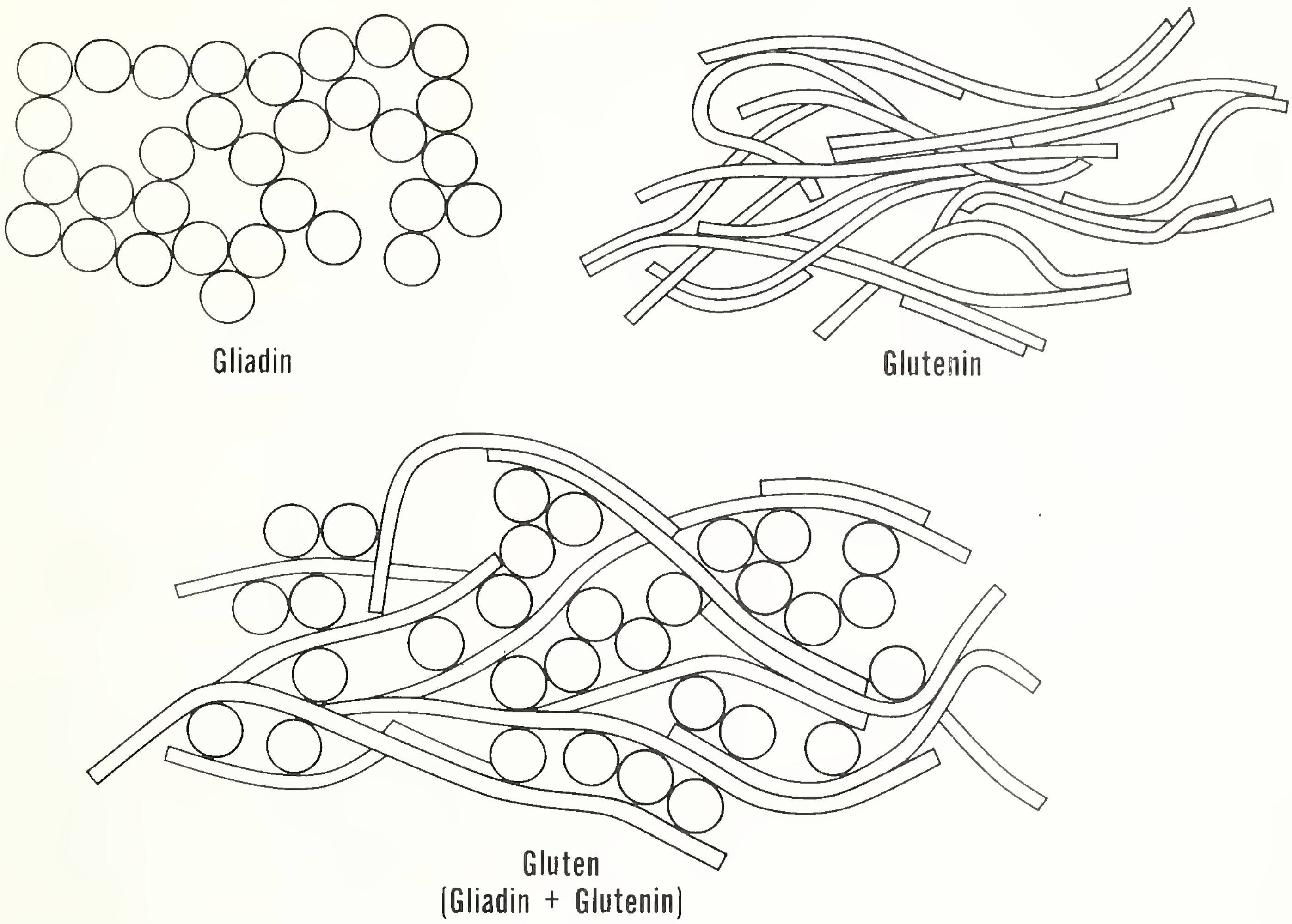

Figure 9. Effect of wheat protein structure on viscoelastic properties of the hydrated proteins.

many functional groups whose interactions stabilize molecular associations. The small uniformly compact molecules of gliadin offer little surface for contact with other molecules. Glutenin, however, consists of many large molecules whose random coils offer numerous opportunities for molecular associations. This complex pattern of association in glutenin promotes cohesion and elasticity. The mixture of gliadin and glutenin results in properties intermediate between those of the separate proteins as shown in the lower diagram. These interactions are further modified by the presence of starch and lipids in flour doughs. Our studies and those elsewhere seek to establish how these components participate in dough formation.

Varietal differences in wheat proteins. A systematic study of the relationship between genetic backgrounds and wheat protein composition and structure is underway in our Laboratory.

The gliadins from wheat of different species and varieties have been compared by column chromatography, amino acid analyses, and gel electrophoresis (6). This combination of analyses permits a more detailed correlation between gliadin protein and its genetic background than was previously

possible in our earlier experiments with starch gel electrophoresis alone. In Figure 10 are shown the ion-exchange separations of the gliadin proteins

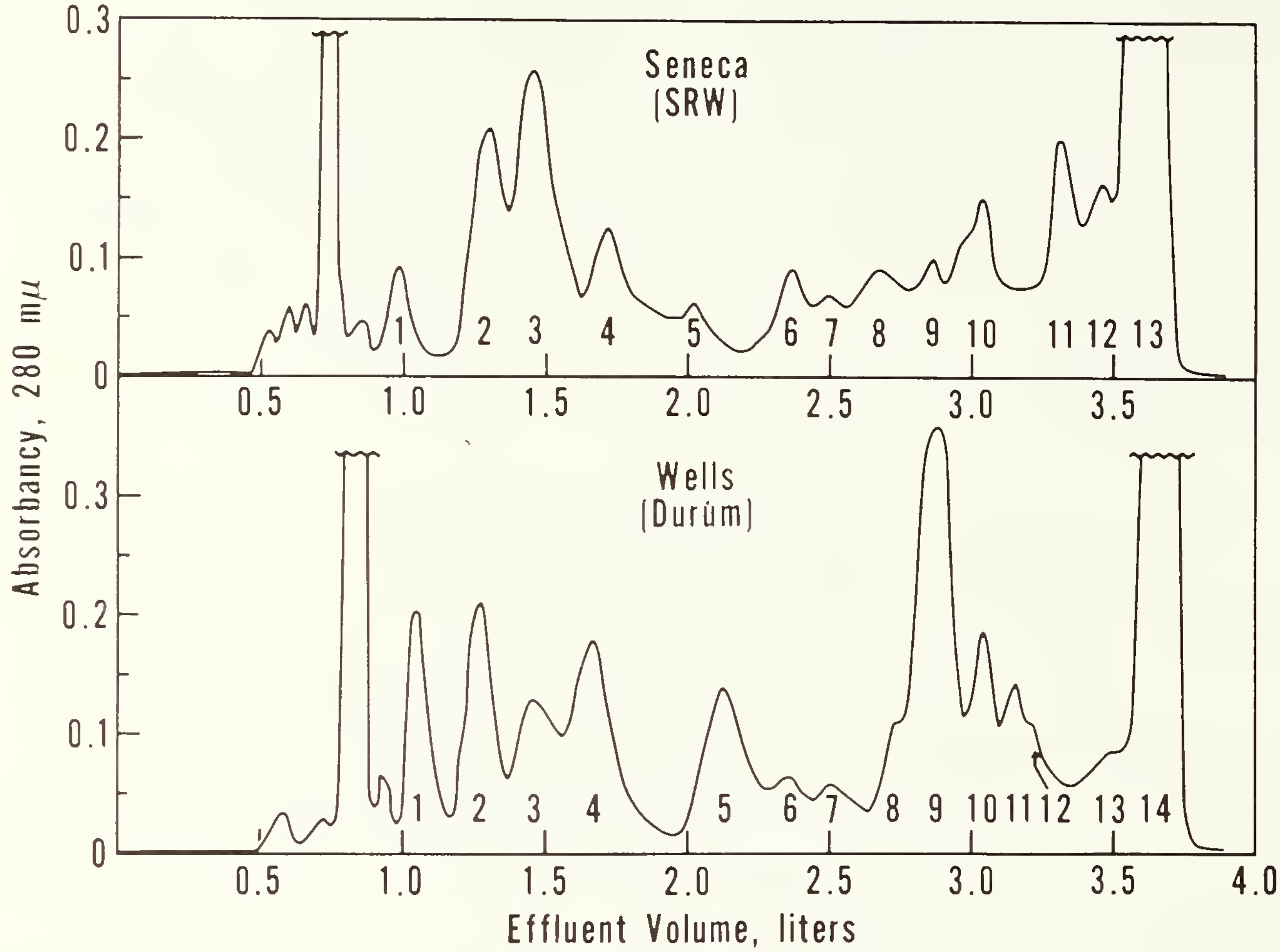

Figure 10. Chromatographic separation of gliadin proteins from Seneca and Wells varieties of wheat flour on SEC columns.

extracted from Seneca, a soft red winter wheat, compared with that of the gliadin from Wells, a durum variety. It is quite evident that marked differences in these chromatographs exist. The wheats are not the same species and so we might expect these great differences. The differences are even more dramatic when we examine the starch gel patterns of the peaks and see that the compositions of the peaks in terms of individual proteins also vary. In addition to major differences observed between contrasting types of grain, small ones are also noted between varieties of the same type of grain. For example, differences between hard red winter wheats of contrasting baking qualities are significant but not great. We have not been able to associate any particular gliadin components with baking qualities.

Since the viscoelastic properties of wheat flour dough are probably determined largely by the nature of the glutenin component of the wheat flour, we are also examining the glutenins to establish if any differences occur among wheat varieties. Starch gel electrophoretic patterns of reduced and alkylated glutenins from a number of wheat varieties are shown in Figure 11. The bands represent different chains of amino acids which constitute the protein and are linked together by disulfide bonds in the native glutenin.

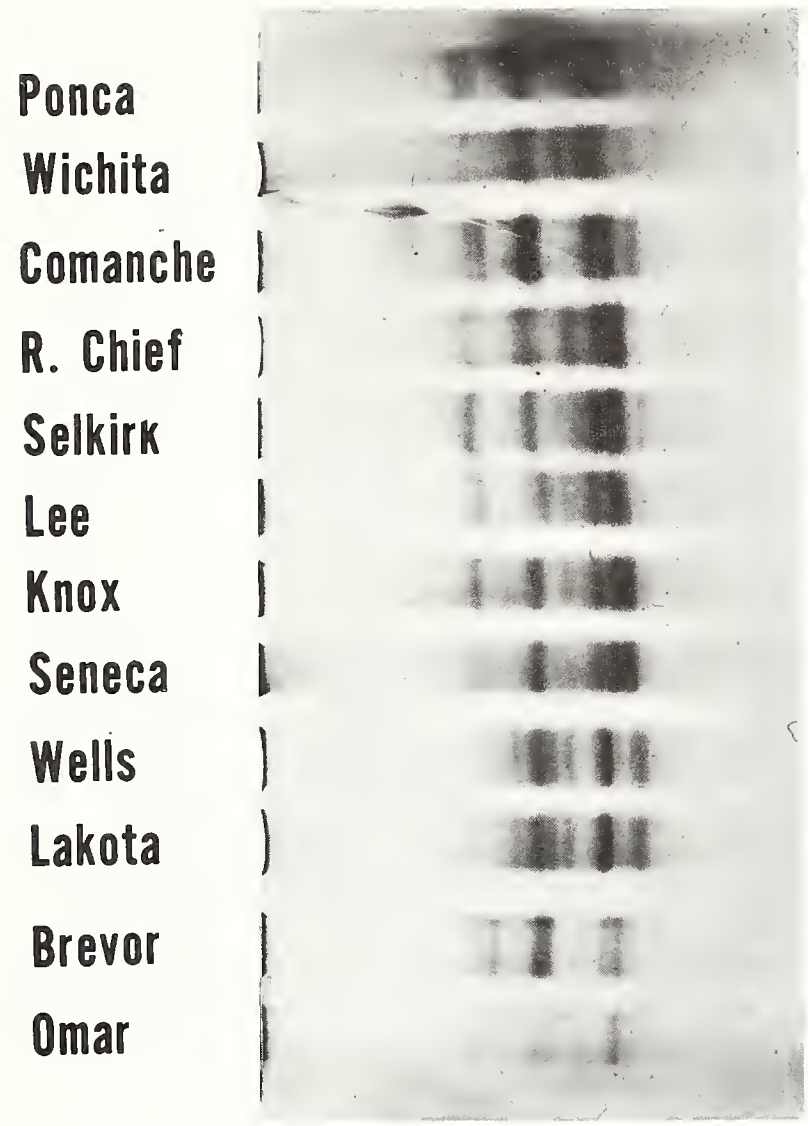

Figure 11. A comparison of the starch gel electrophoretic patterns of reduced and alkylated glutenins from flours of different varieties of wheat.

As with the gliadin, major differences are noted between the patterns of wheats from markedly diverse types. For instance, the Ponca, Wichita, Comanche, and Red Chief patterns, which are hard red winter wheats, differ greatly from Wells and Lakota, which are durums. The soft white winter wheats, Brevor and Omar, vary from the other two types. Of considerable interest are the marked differences between varieties within a given type; for example, the constituent proteins of Ponca, Wichita, Comanche, and Red Chief. Since Red Chief is a poor baking wheat, it would be interesting to note whether the characteristics of its pattern are also present in patterns of other wheats of poor baking quality. These studies are only a beginning. Perhaps as we learn more about the structure of wheat flour proteins, we shall be able to determine the relationship between genetic differences and protein quality among wheat varieties.

Conclusions. We may be optimistic that further progress will be made in isolating and establishing the structures of the many proteins found in

wheat. Our progress so far has been encouraging. The importance of disulfide bonds in wheat proteins to their properties is now fully established. We are gaining a better insight into the role of flour proteins during the formation of dough. Thus we can appreciate better the action of additives and improvers on flour performance. Perhaps from this work will emerge an understanding of why proteins from wheat flours of different types and varieties find different utility in producing bakery and other wheat products. We are confident that research of this type which is being pursued in many laboratories will provide eventual benefits to the wheat breeder, grower, miller, baker, and consumer.

I express my appreciation to my colleagues at the Northern Laboratory for allowing me to use their data for my presentation. Special thanks go to Dr. John Rothfus, Mr. Floyd Huebner, Mr. Alfred Beckwith, and Dr. Harald Nielsen. I also thank Dr. James Pence of the Western Laboratory for permission to use the electron micrographs from work under his supervision at IIT Research Institute.

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ECONOMICS OF WHEAT IN THE NORTH CENTRAL GREAT PLAINS

O. B. Jesness
Head emeritus, Department of Agricultural Economics
Institute of Agriculture, University of Minnesota, St. Paul
Currently, Chairman of the Board, Experience, Incorporated, Minneapolis

"Wheat is wheat." Most Americans likely would accept this as a truism. Members of this audience, however, are aware of the qualifications to which this generalization is subject. As you know, there are several rather distinct classes of wheat--hard winter, hard spring, red winter, durum, and white. Each class has its own production areas with some overlapping. Thus, when we speak of wheat in the North Central Great Plains we usually have hard spring wheat in mind. Durum is important in some areas, especially in northeastern North Dakota. While winter wheat is grown in some parts of the region, especially in Montana, it is a minor part of the total.

The different classes of wheat have distinguishing characteristics which determine their major food uses. These characteristics affect market preferences, outlets, and prices. Competition among classes needs to be recognized as there is a considerable degree of substitutability, as for instance, between hard spring and hard winter in breadmaking. The North Central Great Plains, hence, must be cognizant of its competitive relationship, particularly with areas in the Great Plains to the south where hard winter is dominant. The production rank of the different wheats is indicated by recent crop estimates of 736 million bushels of hard winter, 291 million of red winter, 262 million of white, 229 million of hard spring, and 78 million of durum. Of the estimated total of 1,596 million, hard winter accounted for 46 percent and hard spring 14 percent.

Government farm programs involve additional factors having a bearing on the market and the competitive position of different classes of wheat. Price supports, which were introduced to improve returns to the producers of the commodities included, did not take away from price its function of directing production plans, so the higher prices stimulated production. Acre allotments and other efforts to limit output were adopted but were not adequate to bring production into balance with available commercial markets. Reliance on nonrecourse loans to make supports effective resulted in building up stocks of wheat in the Commodity Credit Corporation far in excess of previous carryovers. Much of this buildup occurred during the 1950's. The needs of the Korean war reduced carryovers to the relatively modest total of 256 million bushels in 1952. By 1960, the carryover was nearing an astronomic total of almost 1-1/2 billion bushels.

Price supports raised the domestic price of wheat well above world levels so export subsidies were required to enable United States wheat to compete in world markets. Lack of prospects for export outlets to absorb the surplus and the costs of carrying encouraged the development of programs of governmental disposal outside regular commercial channels. Prominent among these have been exchanges of wheat for nonconvertible currencies of

underdeveloped nations which lack dollar exchange. India and Pakistan have been among the leading participants. Washington has a penchant for describing such transactions as "sales." That term implies value received in return which is true only to a very limited extent in these transactions. What we have been acquiring is a surplus of foreign currencies for a surplus of wheat. The operation is essentially a type of donation rather than a sale as far as American taxpayers are concerned. This observation is made not in the spirit of criticism but as a suggestion that we recognize the facts of the situation. More recently, emphasis has shifted to grants of long-term credit in lieu of accepting foreign currency. The prospects that such loans eventually will be paid in full are not very rosy.

The level of price supports has been reduced in recent years to bring the domestic price more nearly into line with the world level, thereby improving our export opportunities and reducing very decidedly the amount of subsidy required on exports. As an offset to lower supports, direct payments to cooperating farmers have been instituted, applying particularly to the part of the crop designated as domestic supply. Part of the funds for this purpose comes from the purchase of certificates by processors of wheat for domestic use, the balance comes from the treasury. Reductions in wheat acreage, increased commercial exports, and large out-movement under government programs have brought wheat carryovers down nearer to more normal levels.

The reason why reference is made in this discussion to some features of government wheat programs is that they have an important bearing on the economics of wheat in the region. One point worthy of note in this connection is that government programs have recognized in part only the differences among classes of wheat. Adjustment programs have not been scaled very directly to the surplus situation of each class. Marketing certificates issued to cooperating farmers cover the projected production of a given percentage across the board of their allotments, 35 percent for the 1967 crop and 40 percent for 1968. Actually, there is a sizeable variation among classes in the proportion used domestically. Thus for 1964-66 (Wheat Situation, August 1967) exports of hard winter averaged 490 million bushels while domestic disappearance averaged 308 million. The situation for hard spring was reversed with 77 million exported and 137 used domestically.

Wheat growers have demonstrated most dramatically that the United States has capacity to produce much more wheat than the available commercial market can absorb. Had that capacity been used to the fullest extent, the surplus would have outrun any practicable program of giveaways. This point has not been grasped by those who argue for all-out production. The instinct of our people is to be generous in helping less fortunate nations. However, the realization is becoming more and more general that, while sharing our abundance with others is important, the longer-run solution to the world hunger will be found in increased production in the underdeveloped countries. The United States is not going to end its program of food aid all of a sudden, but it is clear that wheat growers cannot look to foreign aid to provide unlimited outlets.

The outlook for exports of hard spring wheat is mixed. Western Europe is an important buyer but the agricultural policy of the Common Market leads in the direction of increasing self-sufficiency in wheat. France expects to increase its position as a supplier for the other member countries. Population growth is not as rapid in Europe as in some of the underdeveloped nations. Moreover, rising consumer incomes leads to upgrading of diets with less dependence on food wheat. Demand for bread improvement may lead to some increase in the use of hard spring wheat for blending with the soft wheat produced domestically. The Northern Great Plains will experience strong competition from Canada as a supplier of wheat for that purpose.

Prospects for growth in domestic demand are limited. As everyone who has any significant interest in wheat must know by now, per capita consumption of food wheat has experienced a downward trend for a long period. The capacity of the human stomach is limited so the amount of food intake per person in a well-fed country such as the United States is remarkably stable. The makeup of the diet, on the other hand, is subject to change. Rising incomes and improved diets have led to a considerable replacement of such staples as wheat and potatoes by meats and other foods. Population growth has about kept pace with declining consumption of food wheat so that the total quantity consumed has not changed greatly over a considerable period of time. We need to realize that population does not increase at a fixed rate. Many of you will recall the 1930's when the slackening in the birth rate had reached the point where population students were predicting that our total might level out at around 150 million. Now some three decades later we have reached the 200 million total. More than a few seem to believe that the higher rates of the past two decades are destined to continue without interruption. The facts are that the rate has been slowing down during the past decade so some optimistic guesses with respect to future numbers need to be revised. The present prospects for hard spring wheat do not include sizeable expansion in the domestic market.

Competition plays an important role in the economic situation of wheat in the North Central Great Plains. As pointed out earlier, while wheat includes several distinct classes, competition among them is far from negligible. Hard winter will continue to be the principal wheat competitor of hard spring. As can be observed by following quotations at Minneapolis, Chicago, and Kansas City, market prices usually favor hard spring. Premiums paid for protein, while varying with crop conditions, are reflections of quality considerations. Technological developments in milling and commercial baking tend to set a limit on the premium of hard spring over hard winter by facilitating substitution. If the spread becomes too wide, milling processes which increase the protein in flour from hard winter wheat may be good economy. Some changes in baking may permit greater flexibility in kinds of flour used.

The domestic market is the major outlet for hard spring but possible expansion in commercial exports should not be overlooked. Our neighbor Canada is the leading exporter of hard spring and the export market is its major outlet. It has an excellent reputation for the uniformity and quality of the wheat it ships abroad. To be an effective competitor, growers and

handlers of hard spring in the North Central Great Plains need to do the best possible job of providing overseas customers with uniform and high quality wheat.

Another source of competition for hard spring wheat comes from other farm enterprises adapted to the region. The dominant position of wheat in many areas shows that wheat enjoys a comparative advantage. While no drastic change is foreseen, we will do well to be alert to changing markets, preferences, technology, and other factors having a bearing on comparative advantage. Expanding outlets for vegetable oils and meal have brought crops such as soybean into prominence in a relatively short span of years. Research and technology are widening the producing areas of soybeans; but as is the case with corn, climatic factors are important in determining location of production. However, the situation in the market today makes clear that soybeans is not a wonder crop which never will be plagued with surpluses. Moreover, production appears to be expanding in Southern States which adds to the competition which this region will face. Some other oil crops such as sunflowers are attracting attention in some localities but are not likely to become a major replacement of wheat.

Feed grains are suitable for the area and interest is developing in expanding cattle feeding in parts of the region. A consideration not to be overlooked is the ability to compete effectively with the corn belt and the trend towards increasing use of sorghum grain in feeding in some of the South Central States. Barley is one of the feed grains of this area. Some farmers outside areas producing high protein wheat may become interested in growing wheat for feed, emphasizing high yields and feeding qualities rather than milling.

Indications are that the economy of the region will continue to center to a large extent around wheat. Research and technological developments which will lead to higher yields of wheat with desired qualities will continue to be important. The adoption by growers of improvements and better management likewise is important. Indications are that consolidation of farms into larger individual units will continue. By and large these units will gain from better management and will provide the farm family with better incomes and higher levels of living.

No region holds a monopoly on improvements so every region needs to be alert to developments elsewhere. While soft white wheats of the Pacific Northwest are not as direct competitors with hard spring as is hard winter, the North Central Plains cannot escape the consequence of the development and rapid adoption of Gaines wheat. The result of Gaines wheat is to improve the competitive position of the Pacific Northwest in wheat. Yields of wheat have been improving in recent years and will continue to do so. There is always the possibility that a counterpart of the Gaines development may be developed and, if so, some of you are likely to have a part in it.

The success achieved in corn as a result of the hybrid development has stimulated the imagination relative to a similar development in wheat. Reports of the achievement of success in developing a method of producing

hybrid wheat led some enthusiasts to predict a revolution in wheat production. As you know better than I, the process in wheat is different from that in corn. The objective is not only that of obtaining increased yields but it also has to be concerned with milling qualities, resistance to disease, adaptation to climatic conditions and the like. This calls for a continuous application of research skills.

As observed previously, wheat will remain important to this region. How important will depend in no small measure on how effectively farmers adapt their production to market needs and preferences, both as to quantity and quality. Important also will be the contribution of research and technology.

POTENTIAL FOR GROWTH OF THE DURUM INDUSTRY

Robert M. Green
Executive Secretary, National Macaroni Manufacturers Association
Palatine, Illinois

If the past is prologue, then the future is bright for the durum industry.

Going back some 20 years, the macaroni industry was calling for 2 million acres to be planted to durum to produce a crop of 40 million bushels. Macaroni consumption had jumped during World War II because macaroni products were not rationed and meat required red ration stamps. Then with the end of hostilities in Europe, there was a lush export market for macaroni products going to Southern Europe, and this had many small plants working around the clock, accounting for a quarter of total industry production.

In the crop year 1946-47 production was 36 million bushels, with July 1 stocks just under 5 million bushels, giving a total supply of 41.5 million bushels.

To stimulate grower interest in durum, the National Macaroni Manufacturers Association bought paid space in newspapers in the growing area and participated in the North Dakota State Durum Show by offering prizes and having its members attend the event.

Acreage did increase and production rose until the disastrous period in the early 50's when 15B rust devastated the crop.

In the crop year 1953-54, less than 14 million bushels of durum were produced, and total supply was about 20 million bushels. The macaroni industry went on a blend of half durum/half bread wheat. The following year, less than 5 million bushels of durum were produced, and total supplies were under 10 million, so the industry went to three-quarters bread wheat and one-quarter durum.

A crash research program was showing signs of hope in the year 1955-56 with almost 20 million bushels produced, so the industry was back to a 50/50 blend, and by 1956-57 semblance of normalcy was restored with a crop of better than 38 million bushels.

Better than the recitation of any statistics, this experience in the 1950's proved that macaroni consumption went up or down with the availability of durum wheat.

By this time the industry's product promotional program was in high gear. It had been established in 1948 when the Marshall Plan went into effect cutting off the export market overnight. Instead, American funds for equipment and the purchase of American wheat aided the suffering Western Europeans.

But product promotion was not sufficient to offset the decline in quality, and consumption declined during the rust years.

Once consumption was on the increase again, the macaroni industry had problems of getting sufficient acreage, because growers who had had sad experiences with durum were not going back to it quickly enough, so there was a period of feast and famine with widely fluctuating prices.

While macaroni manufacturers want durum as their standard of quality and pay a premium for it, there is an economic point of no return where other wheats become substitutes in order to keep the price level competitive with other carbohydrate foods such as potatoes and rice.

The macaroni industry, then, was delighted when the development of export business for durum began with efforts of the North Dakota State Wheat Commission and Great Plains Wheat, Inc. The sale to Russia of some 20 million bushels in 1964 seems to have been a turning-point. Since that time exports have ranged from almost 10 million bushels in 1965, to more than 33 million in 1966, and better than 47 million in the past crop year.

At a recent seminar at the Minneapolis Grain Exchange, Clifford Pulvermacher, Director of Procurement and Sales Division, Agricultural Stabilization and Conservation Service, said that exports of durum are expected to be off somewhat from last year. He pointed to the improved crop situation in North Africa and Western Europe affecting exports to Algeria and France. He also said that Argentine durums are expected to be available in larger quantities. Ben Nordemann of Continental Grain said that the main problem in durum exports was that Algeria did not like us any more. But then there were reports that Algeria came into the market for some 5 million bushels.

Japan and certain Western European countries hold the best potential for modest increases for U.S. durum. The Department of Agriculture, through the subsidy program, is making every effort to maximize Asian dollar exports.

At the Durum Show 2 years ago, Dan Amstutz of Cargill, Inc. made the statement that to develop desired foreign markets, we must first be recognized as a consistent and regular supplier. We cannot be in and out of the market. Secondly, we must be competitive on quality, and it was apparent that foreign buyers did not think our kernel size was large enough although we had excellent color. Finally, said Mr. Amstutz, the third necessary factor to develop foreign outlets was that we had to be competitive in price. In addition to the United States, Canada, Argentina, and normally North Africa have supplies to sell to the only one notable import area, Western Europe.

Canada produces as much durum as we do, and their domestic industry is only a tenth the size of ours, so 90 percent of their production must go to export channels. As regular suppliers, they know and want to keep their export business. We got our foot in the door largely because of their huge commitments to Russia and China for large volumes of all wheats that curbed their ability to meet increasing demands in Europe.

It is interesting to note that while our exports of durum are on the rise, the exports of macaroni are on the decline. Back in 1958, macaroni exports just about offset imports at around 7 million pounds per year. Since that time, exports have declined to slightly less than 2 million pounds, but imports have increased to over 13 million pounds--much of this from Canada where wheat and labor costs are lower and where the markets of New England and Western New York State offer as many macaroni consumers as the whole of Canada.

Domestic consumption of macaroni continues to rise. The Super Market Sales Manual prepared by Chain Store Age in July 1967 reported that macaroni products continued a 10-year upward swing in 1966. The category posted an 8 percent increase over 1965 in dollar volume (54 percent better than 1962) to reach an all-time high of $172,600,000.

Food Topics, in their annual survey of Consumer Expenditures for Grocery Products, sets the total value of domestic consumption of macaroni products at $432,250,000. They say that some 68 percent goes through grocery channels with 32 percent going to institutional and industrial uses. Their surveys show an increase in macaroni products sales volume of 4.9 percent in 1966, 4.2 in 1965, 3.5 in 1964, 5.5 in 1963, and 6.5 in 1962. This is considerably better than the annual rate of total personal consumption expenditures for all food, which runs around 2.4 percent.

This increase is accounted for by the continuing popularity of dry macaroni products, the introduction of combination dinners or dinner bases in packaged form, and the rise of ethnic foods in frozen form with such Italian specialties as lasagna, manicotti, and cavatelli, plus the old standbys of spaghetti with meat sauce and macaroni and cheese.

An economic study of the macaroni industry by an important research organization recently observed that: The manufacture of macaroni products involves a relatively simple processing of materials that can be obtained from well established sources of supply. The major requirements for success in this industry are efficiency in processing operations, proficiency in marketing, and the ability to develop new products and to introduce them to the markets.

To date the industry has been doing an excellent job, so the future for the durum industry looks good. This year intentions to plant durum were the largest on record since 1949. Acreage was closer to 3 million than to 2 million. The October 1 estimate sets production at 68,860,000 bushels; not bad for a crop that was buried at least twice; with late spring planting, and drought through a long hot summer.

The durum mill grind for the first 8 months of 1967 is running 4.8 percent ahead of a year ago.

SPRING WHEAT VARIETIES; THEIR DEVELOPMENT, PRODUCTION, AND UTILIZATION

L. D. Sibbitt and K. A. Gilles
Department of Cereal Chemistry and Technology
North Dakota State University
Fargo, North Dakota

The development, production, and utilization of spring wheats in the upper Great Plains region presents a series of dynamic events. After new wheat varieties are released, producers choose the variety or varieties they believe are best suited to meet the needs and problems of a particular area. Often the need is for more disease resistance, higher yields, stronger straw, resistance to insects, resistance to shattering, or superior quality to gain a market preference.

While it is virtually impossible and probably undesirable to present a review of all of the spring wheat varieties produced in the upper Great Plains of North America, an attempt will be made to cite only the varieties that became of commercial significance.

Hard Red Spring Wheats

The first variety of importance to be grown in the spring wheat area was Red Fife, introduced into Canada about 1842 from Poland or Russia. Table 1 shows the varieties, the pedigree or cross, then the origin. Next is the approximate date the wheat was released, distributed, or first grown in the United States. The next three columns list the quality properties--farm or agronomic, milling and baking. These are ranked into three classifications--good, fair, and poor. The cultivation of Red Fife in the United States commenced about 1870 and North Dakota's early reputation for the production of "high quality" "hard" wheat was made with Red Fife.

Bluestem, introduced about 1890, was a later ripening variety than Red Fife, but was very satisfactory when growing conditions were good. Attempts were made by agricultural experiment stations and individual growers to improve these wheats by selecting outstanding appearing heads of grain from fields of wheat. However, Red Fife, Bluestem, and the selections were seriously lacking in resistance to stem rust and were destined to be replaced.

The first hybrid cross to be grown in the northern Great Plains was Velvet Chaff. Prior to this, new varieties were merely selections taken from fields of wheat. This wheat came into more general production after 1905 and continued to increase for a number of years; in 1919, it represented about three quarters of a million acres in North Dakota. The yield was not particularly high, but it matured a little earlier than either Red Fife or Bluestem and showed a better tolerance to the plant disease, rust. The gluten quality was lower which resulted in less market appeal.

The first HRS wheat cross of major importance was a selection from a cross between Red Fife and an early ripening wheat from Calcutta. This variety, Marquis, came into production in the United States in 1912, and had

Table 1. Important Hard Red Spring Wheat Varieties of the Upper Great Plains

Variety	*Pedigree*	*Origin*	*Date*[a]	*Quality Properties*[b] *Farm*	*Mill*	*Bake*
Red Fife		Germany	1860	G	G	G
Bluestem		U.S.	1890	F	F	G
Velvet Chaff	Ladoga × Red Fife	Canada	1895	F	F	P
Marquis	Red Fife × Hard Red Calcutta	Can.—Ont.	1912	G	G	G
Ruby	Red Fife × Downy Riga		1915	F	G	G
Prelude	Fraser × Gehun	Canada	1915	P	....	....
Kota	Selection—Monad (durum)	Russia	1919	F	P	P
Kitchener	Selection—Marquis	Canada	ca. '20	F	F	F
Quality	(White wheat)	U.S.	ca. '20	F	P	P
Garnet	Preston × Riga	Can.—Ont.	1920	F	F	F
Ghirka		Russia	ca. '20	P	P	P
Red Bobs	Selection—Early Triumph	Can.—Alta.	1925	F	F	F
Supreme	Selection—Red Bobs	Canada	1925	P	F	F
Progress	Selection—Java	US.—Wis.	ca. '25	P	P	P
Axminster	(White wheat)	Canada	ca. '25	P	P	P
McMurachy	Selection—Garnet	Canada	1925	F	P	F
Reward	Marquis × Prelude	Canada	1925	G	G	G
Ceres	Marquis × Kota	U.S.—N. D.	1925	G	G	G
Hope	Marquis × Emmer (Spelt)	U.S.—S. D.	1927	F	P	P
Montana King		Canada	ca. '28	P	P	P
Marvel	Velvet Chaff × Marquis	U.S.—S. D.	1928	F	P	P
Marquillo	Iumillo (durum) × Marquis	U.S.—Minn.	1928	F	P	P
Thatcher	Iumillo × Marquis—Kanred × Marquis	U.S.—Minn.	1934	G	G	G
Apex	H 44[c] × Double Cross[c] × Marquis	Can.—Sask.	Ca.'35	G	F	F
Regent	H 44 × Reward	Can.—Man.	1939	G	F	G
Renown	H 44 × Reward	Can.—Man.	1939	G	F	F
Rival	Hope × Florence	U.S.—N. D.	1939	G	G	G
Pilot	Hope × Ceres	U.S.—N. D.	1939	F	G	G
Coronation	Pentad × Marquis	Canada	1940	G	P	P
Vesta	Ceres × Hope × Florence	U.S.—N. D.	1942	F	G	F
Mida	Ceres × (Hope × Florence) × RL 625	U.S.—N. D.	1944	G	G	G
Newthatch	(Hope × Thatcher) × Thatcher^{3}	U.S.—Minn.	1944	G	G	G
Rescue	Apex × New Zeland—S 615	Can.—Ont.	1945	G	F	F
Spinkcota	(Preston sel. × Red Durum) × Preston sel.	U.S.—S. D.	1945	G	P	P
Cadet	Merit × Thatcher	U.S.—N. D.	1946	F	G	G
Redman	Regent × Canus	Can.—Man.	1946	F	G	G
Rushmore	Rival × Thatcher	U.S.—S. D.	1949	G	G	G
Lee	Hope × Bobin^{3}—Gaza	U.S.—Minn.	1951	G	G	G
Chinook	Thatcher × S 615-11	Can.—Ont.	1952	F	G	G
Selkirk	(McMurachy × Exchange) × Redman^{3}	Can.—Man.	1953	G	G	G
Conley	[(McMurachy—Exchange × Redman^{2}) × Thatcher] × Lee	U.S.—N. D.	1956	F	G	G
Canthatch	Thatcher^{6} × Kenya Farmer	Can.—Man.	1960	F	G	G
Pembina	Thatcher × (McMurachy—Exchange × Redman^{3})	Can.—Man.	1961	G	G	G
Justin	N.D. 40 × Conley	U.S.—N. D.	1962	G	G	G
Crim	(Klein Titan × Thatcher) × (K 58 × Newthatch)	U.S.—Minn.	1962	F	F	F
Chris	(Frontana × Thatcher^{3}) × (II-44-29 × Thatcher^{2})	U.S.—Minn.	1965	G	G	G
Manitou	[(Thatcher^{7} × Frontana) × (Thatcher^{6} × Kenya Farmer)] × (Thatcher^{6} × P.I. 170925)	Can.—Man.	1965	G	G	G
Fortuna	(Rescue × Chinook) × (Frontana × II-44-29)	U.S.	1966	G	G	G

[a] Approximate date released, distributed, or first grown in the U.S.
[b] G=good; F=fair; P=poor.
[c] H 44, selection from emmer × Marquis. Double Cross, selection from (Marquis × Iumillo) × (Kanred × Marquis).

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many characteristics of its Fife parent, though ripening earlier permitted it to escape heat and rust injury better than Red Fife or Bluestem. With the serious losses in yields due to rust in 1914 and 1916, the earlier ripening Marquis replaced the older varieties. By 1919, Marquis was grown on about 67 percent of the acreage of North Dakota. Although not resistant to stem rust, Marquis continued to be the predominating variety for several additional years and particularly so in western North Dakota and Montana.

The milling and baking quality of Marquis, when not affected by rust, was excellent. It is one of the few wheats that has withstood the test of time; Marquis is still the standard of quality used by Canada in its wheat grading system.

As serious losses of grain production due to wheat rust continued, an increasing demand arose for new varieties. Development, introduction, and promotion of many new wheat varieties followed as shown in this table. Some of these new wheats were not resistant to rust nor were they superior to Marquis. Some matured earlier than Marquis and, therefore, had a better chance of escape from the rusts. Others yielded well and produced grain of high test weight with a very good kernel appearance. Reward, probably the most satisfactory of these, was susceptible to stem rust, but was 4 to 8 days earlier than Marquis and sometimes this characteristic helped it to escape stem rust injury. The milling and baking properties were considered as satisfactory.

Ceres was the next major wheat to be grown. It was a hybrid selection moderately resistant to rust, and yielded well under conditions of drouth and heat. As a result, production increased rapidly and by 1934, Ceres represented about 45 percent of the HRS wheat acreage in North Dakota.

One of the first stem rust-resistant wheats to reach the terminal markets was Marquillo. It was a cross between a durum (Iumillo) and a HRS (Marquis). The outstanding feature of this wheat was its ability to outyield Marquis in a rust year. The milling and baking value, however, was considerably below Marquis.

A major improvement resulted with the release of Thatcher in 1934. This wheat had good resistance to stem rust and yielded more consistently than any of the earlier varieties. It was grown extensively after the severe rust years of 1935, 1937, and 1938 when the new rust conditions seriously damaged Ceres. By 1941, Thatcher represented about 60 percent of the HRS acreage in North Dakota. This wheat was superior in milling and baking quality to any of the varieties grown up to that time. In fact, it is still grown with considerable success in nonrust areas and is being used in some instances as a standard of quality.

The next wheats of importance were Rival and Pilot in 1939. Both varieties were classed as moderately resistant to stem and leaf rust and were excellent in bushel yield; the milling and baking qualities were satisfactory.

In 1944, Mida was released. It was moderately resistant to stem rust, moderately susceptible to leaf rust, and yielded well with a high test weight. The milling and baking properties were satisfactory and were classed as having medium strength. By the late forties, Mida occupied about 40 percent of the HRS wheat acreage in North Dakota.

Other new varieties introduced during the forties were Newthatch, Spinkcota, Cadet, Redman, and Rushmore. All were moderately resistant to stem rust, however, none of these were grown to any great extent for one reason or another.

Rescue, which is a sawfly-resistant variety, was released about 1945 for distribution in the sawfly areas only. The milling and baking properties, however, were only fair. Chinook, released in 1952, was to provide a better quality wheat than Rescue for the sawfly area.

The change in the races of stem rust in the northern Great Plains may occur very suddenly. In 1 year (1950) Race 15 B, which was not previously present in this area, became the most prevalent race. None of the varieties grown or available at that time were resistant to this virulent race of rust and to meet this situation, new sources for resistance were sought.

To more rapidly increase the quantity of seed and to decrease the time required for release of new varieties, a new program was introduced in 1953. Small quantities of northern grown seed were planted in Arizona and Mexico. The harvest of these increased plots was returned in time for spring seeding in the upper Great Plains, thereby producing two crops of wheat per year. This program has been tremendously successful in producing new wheat varieties in a shorter time than was heretofore possible.

Lee was the first variety that had acceptable leaf rust resistance. It was also found to have some tolerance to 15 B and so it came into increasing use during the early fifties. By 1954, it was the leading HRS wheat variety.

The first variety to be developed and released for resistance to 15 B stem rust was Selkirk. Because of its resistance and satisfactory yield, it rapidly became the predominant variety occupying at one time more than 70 percent of the acreage. Although it was classed as a medium strength wheat, the milling and baking properties were considered satisfactory.

Conley was moderately resistant to the stem rusts but susceptible to leaf rust. Although it had excellent milling and baking properties, it never was completely acceptable to the growers.

Within the past 5 years, only five varieties have been grown commercially in significant amounts. Canthatch, released in 1960, was susceptible to leaf rust and resistant to 15 B stem rust. Even at its peak popularity in 1964, it occupied less than 10 percent of the acreage.

Pembina, possibly the strongest wheat to be grown in the spring wheat area up to 1961, was more resistant than Selkirk to 15 B stem rust and was

moderately resistant to leaf rust. About 18 percent of the 1965 HRS acreage in the upper Great Plains was seeded to this variety.

Justin, released in 1962, is possibly the strongest wheat ever to be released and widely grown. Justin is resistant to stem rust race 15 B and moderately resistant to leaf rust and is consistently superior to Selkirk in test weight per bushel, protein content, water absorption, dough handling properties, mixing time, and tolerance and dough elasticity. It has been estimated that 75 percent of the 1966 HRS wheat crop in North Dakota was Justin.

Crim was better than Selkirk in stem rust resistance and also the source of this resistance was different from Selkirk. The milling and baking properties were somewhat similar to Selkirk but much inferior to Justin. The general agronomic characteristics in 1965 were rather disappointing, particularly in the eastern part of North Dakota and it soon lost its appeal to the producers.

Chris has proved relatively acceptable to the growers and in 1967 it was estimated that this variety occupied about 33 percent of the North Dakota hard red spring wheat acreage. The overall milling and baking properties are better than Crim and Selkirk but not as good as Justin.

Manitou was released in Canada in 1965. This wheat obtains its rust resistance from a different source than that used in any of the preceding 15 B resistant varieties. The milling and baking properties, although not as strong as Justin, are quite satisfactory. This fall there are limited quantities entering commercial channels for the first time in the United States.

The last variety listed on this table is a sawfly resistant wheat which has been named Fortuna. This wheat combines resistance to wheat stem sawfly, with good resistance to prevalent races of leaf and stem rust. The milling and baking properties are somewhat better than either Rescue or Chinook. However, it will be about 2 years before any of this wheat will reach commercial markets in significant amounts.

Red River 68. During recent months, considerable publicity has been emanating from a private seed company on a semidwarf hard red spring wheat variety known as Red River 68. It is claimed that this variety has high yield potential relative to other commercial varieties now grown in the upper Great Plains. Also, it is said to be highly resistant to lodging and because of the short straw, larger quantities of fertilizer can be utilized than are normally used on conventional wheats.

There is a paucity of information concerning the milling and baking quality characteristics of Red River 68. Recently, five samples of this wheat grown in the area of Grand Forks, North Dakota, were milled by the USDA and evaluated by 15 industry, State, and Federal laboratories along with comparable samples of the commercial varieties Chris and Manitou.

Economically important problems encountered in the first year of broad scale industry tests include a substantial reduction in the production of bakery flours from grain of Red River 68 and an excessively long mixing requirement for the new wheat would slow bread production in modern baking plants. The ability of Red River 68 to be blended with other types of wheat was also substantially less acceptable than current spring wheat varieties.

In spite of the recommendations of the Crop Quality Council, this variety was released. Because Red River 68 has not been tested over several years, its future is uncertain.

A remarkable phase of this story is shown in Table 2. During the past

Table 2.--Hard red spring wheat production[1/]

Year	Yield, bu./acre	Increased yield basis, % 1920	Increased yield basis, % 1950	Production, million bushel	Acreage, million acres
1920	8.6	100	--	55.6	6.5
1925	11.5	134	--	70.5	6.1
1930	10.2	119	--	69.9	6.8
1935	6.0	70	--	36.6	6.1
1940	12.0	140	--	67.9	5.7
1945	15.5	180	--	124.6	8.0
1950	14.0	163	100	91.5	6.5
1955	15.5	180	111	96.6	6.2
1960	19.5	227	139	100.6	5.2
1965	24.5	285	175	118.1	4.8
1967	22.0	256	157	125.4	5.8

1/North Dakota Crop and Livestock Reporting Service, USDA.

four and one half decades, since independent records were kept for durum and HRS wheats, the production capabilities per unit area of land have increased tremendously. For example, in 1920, 6.5 million acres of land produced 55.6 million bushels of HRS; whereas, in 1965, 4.8 million acres of land produced 118.1 million bushels. Since the rust epidemic of 1950, the HRS acreage has been reduced by U.S. government allotments, however, the total production of wheat has increased because scientific research has provided better varieties and because the environmental conditions for higher production have been very favorable. Since 1950, the yield of HRS wheat has increased 75 percent; if one were to compare the 1965 yield with that of 1920, the increase amounts to 185 percent.

A major scientific breakthrough has recently occurred which leads to the possible production of true hybrid wheat, which may do for the wheat producers what hybrid corn has done for the corn growers. Table 3 shows an example of pertinent agronomic and quality data for two generations of hybrid wheat and the respective parents. These quality data are the first to be presented from our laboratory on hybrid wheat material. This table shows data for the F_1 and F_2 wheat for the cross, Chris and Penjamo 62. There does not appear to be any significant difference in the agronomic data with the exception of yield of bushels per acre and possibly date of maturity. In the

Table 3.--Agronomic and quality data on hybrid wheat

Variety	Maturity, days	Yield,[1/] bu./acre	Wt./1,000 kernels, g.	Test wt., lb./bu.	Wheat protein, %	Flour yield, %	Loaf volume, cc.	Mixogram class
Chris	120	49.6	30.5	60.2	16.6	62.3	179	6
Penjamo 62	116	46.0	32.0	59.2	13.1	42.7	154	2
F_1	109	63.4	35.5	61.0	14.5	53.3	160	4
F_2	117	59.8	33.0	59.0	15.3	54.7	160	4

1/ Calculated yield.

instance of yield, there is a 28 percent increase in the first generation, and a 21 percent increase in the second generation over the parent Chris. This loss of hybrid vigor is typical; the progeny of hybrid wheats tend to produce lower yields. The test weight in the F_1 was higher than either parent but lower than either parent in the F_2 progeny. The other quality data fell about midway between the parents.

It appears to be, on the basis of these limited data and other data not presented here, that the yield potential is quite great in most instances for hybrid HRS wheat and the quality results, although not conclusive, appear to fall midway between the two parents.

The key to producing hybrid wheat still centers around converting the normally self-fertilized wheat plant, for one generation only, into a male sterile plant that can be cross-fertilized. The successful system must provide for achieving mass male sterility followed by reconversion to self-fertility. A major drawback is that the system is often environmentally unstable. That is, it may work in one area and not in another. More research must be done before hybrid wheat becomes economically feasible.

Durum Wheats

The introduction and establishment of durum wheat can be considered a step of major importance not only for the state of North Dakota, which produces most of the crop in the USA, but for Canada as well. The early durum varieties were principally of Russian origin and unfortunately the pedigree was unknown.

A list of durum wheat varieties, arranged in chronological order of release or wide acceptance in the USA, is shown in Table 4. The principal quality characteristics, agronomic, milling, and macaroni processing are ranked in three classifications; good, fair, and poor.

The first variety of importance to be grown in the upper Great Plains was Arnautka. This wheat was introduced into the United States in 1856, but did not come into extensive production until about 1900. It was resistant to leaf rust and moderately resistant to the stem rusts prevalent at that time. Although classed as satisfactory from a milling standpoint, it was only fair for the production of macaroni.

Table 4. Important Durum Wheat Varieties Grown in the Upper Great Plains

Variety	Pedigree	Origin	Date[a]	Quality Properties[b] Farm	Mill	Macaroni
Arnautka		Russia	1856	F	G	F
Peliss		Algeria	1900	F	P	P
Kubanka		Russia	1900	G	G	G
Pentad		Russia	1911	F	P	P
Mindum	Selection from Hedgeron	U.S.—Minn.	1917	G	G	G
Golden Ball		So. Africa	1918	F	P	P
Carleton	Vernal (Emmer) × Mindum[3]	U.S.—N. D.	1943	G	G	G
Stewart	(Mindum-Vernal) × Mindum[2]	U.S.—N. D.	1943	G	G	G
Vernum	(Mindum-Vernal) × Mindum[4]	U.S.—N. D.	1947	F	G	G
Nugget	(Mindum-Carleton) × (Heiti-Stewart)	U.S.—N. D.	1950	G	G	G
Sentry	LD 308 × Nugget	U.S.—N. D.	1954	G	G	G
Langdon	(Mindum-Carleton) × Khapli × LD 308 × Stewart × Carleton	U.S.—N. D.	1956	G	G	G
Ramsey	Carleton × PI 94701	U.S.—N. D.	1956	G	G	G
Towner	Carleton × PI 94701	U.S.—N. D.	1956	G	G	G
Yuma	(Mindum-Carleton × Khapli) × LD 308	U.S.—N. D.	1956	F	G	F
Wells	Sentry × (LD 379—LD 357)	U.S.—N. D.	1960	G	G	G
Lakota	Sentry × (LD 379—LD 357)	U.S.—N. D.	1960	G	G	G
Stewart 63	Stewart[5] × ST 464	Can.—Sask.	1964	G	G	G
Leeds	LD 357[4] × (ST 464—LD 357) × Wells	U.S.—N. D.	1966	G	G	G

[a] Approximate date released, distributed, or first grown in the U.S.
[b] G=good; F=fair; P=poor.

In 1900, Peliss, also known as Pelissier which had its origin in Algeria, was distributed. It was fairly well adapted as a drouth resistant variety. Fortunately, as the durum area gradually moved eastward, this variety was replaced by better, agronomically acceptable wheats.

Kubanka was introduced into the United States from Russia about 1900. After the rust years of 1916 and 1919, Kubanka replaced much of the Arnautka acreage. The milling and macaroni qualities were acceptable. Although a number of selections were made from this wheat, very little, if any, of these are grown commercially at the present time.

Pentad, which is a red durum, also was introduced from Russia about 1903. It was released to North Dakota growers about 1911, and was highly resistant to the strains of stem rust prevalent at that time. The milling and macaroni properties were very unsatisfactory and it was recommended only as a feed wheat. It is so unsatisfactory that the Federal Grain Standards of both Canada and the United States provide a separate class for Red Durum to discount this type of wheat.

The first breakthrough for quality amber durum wheat came with the release of Mindum in 1917. Although only moderately resistant to rust, it is an excellent yielder and ranks quite high in macaroni making quality. It is still grown to some extent in nonrust areas of the upper Great Plains and, in some instances, currently is used as the "standard" for quality evaluations.

Other varieties or selections from established varieties were introduced during the next 20 years. However, for one reason or another, none of these were grown to any great extent.

Carleton and Stewart, rust resistant durums but not resistant to stem rust race 15 B, were released in 1943. By 1949, both of these wheats occupied more than 50 percent of the durum acreage or over 3 million acres in North Dakota. Stewart proved to be more dependable in yield of bushels per acre than Carleton and was grown more extensively. The milling and macaroni processing characteristics were distinctly better than Mindum. In particular, the macaroni color for both was classed as excellent with Carleton holding a slight edge over Stewart.

Supplementing Carleton and Stewart was an earlier ripening rust resistant variety named Vernum, which was released in 1947. It was recommended for production only in the southern durum area where earliness is considered important. This variety enjoyed only limited acceptance and currently is not a factor in commercial channels.

Nugget was released early in 1950. It was the first wheat to be released with the highly pigmented variety "Heiti," obtained from India, as one of its parents. The kernels from this variety were a deep amber color which carried through to the macaroni. It produced a more highly pigmented macaroni than any variety up to this time. It was, however, deficient in gluten properties. This property and the 15 B rust epidemic, which was to come, stopped this wheat from gaining much prominence.

In an attempt to increase gluten strength, combined with greater earliness and some tolerance to 15 B stem rust, Sentry was released. It proved to be a reasonably acceptable stopgap variety until wheats with 15 B resistance could be developed.

The 1950 disasterous rust epidemic, attributed to stem rust race 15 B, very nearly eliminated the entire durum wheat crop. While race 15 B had been known for some time, it had not been observed in the major wheat producing areas of North America prior to 1950. It was fortunate that the North Dakota Agricultural Experiment Station, in cooperation with the USDA, had earlier begun a crossing program for durums using the resistance to race 15 B found in Khapli, and another wheat which had been introduced from Palestine.

Langdon, Ramsey, Towner, and Yuma were released simultaneously in 1956. They were also the first durums to be released with 15 B rust resistance. Each of the varieties displayed different agronomic and quality characteristics, and it soon became apparent that Langdon was giving the best results for the growers. Fortunately, it was also the best of the four for the production of pasta products.

In 1960, Wells and Lakota were released. Although the parentage of both wheats was the same, these progeny were distinctly different. The parentage of these wheats consists of Sentry, Mindum, Stewart, Heiti, Vernum, Khapli, Nugget, and Carleton. Both Wells and Lakota are resistant to leaf

rust and to 15 B stem rust. Wells is slightly lower in test weight than other commercial varieties, and both are lower in semolina yield and weight per 1,000 kernels. The gluten strength of Wells, as measured by the Farinograph, is moderately weak. Lakota is lower than Wells in test weight but possesses a much stronger gluten. Both produce excellent macaroni products. However, Wells is preferred from the producers' standpoint, in fact, it is so widely accepted that this year, Wells represented about 88 percent of the durum acreage in North Dakota.

Stewart 63 was released in Canada in 1963 and entered North Dakota in 1964. It combines the desirable field and quality characteristics of the original Stewart with 15 B rust resistance. The test weight, kernel size distribution, weight per 1,000 kernels, and semolina yield are better than either Wells or Lakota. The macaroni products are fairly satisfactory in color, though considerably lower than either Wells or Lakota.

A little over a year ago, a new rust resistant, large kerneled durum named Leeds was released jointly by the North Dakota Agricultural Experiment Station and the USDA. Among the major needs in the durum improvement program have been greater protection against stem rust, larger kernels, and heavier test weight. In the United States, the predominating varieties, Wells and Lakota, have been sufficiently resistant to prevailing races of stem rust, but both have small kernels and somewhat low test weights which place them at a disadvantage in the export market. For the past number of years, the selection pressure has been directed toward development of varieties similar to Wells and Lakota in maturity and plant type but with better rust resistance and improved test weight and weight per 1,000 kernels. Leeds represents the first such combination to be developed in the North Dakota-USDA program.

Table 5 shows comparative pertinent quality data for Mindum, Wells,

Table 5.--Average quality data (North Dakota field plots)

Variety	Test wt., lb./bu.	1,000 kernels wt., g.	Wheat protein, %	Semolina protein, %	Semolina yield, %	Macaroni color1/	Farinograph
Mindum	60.7	31.4	11.7	11.1	52.9	8.2	5
Wells	61.7	30.8	13.0	12.3	53.1	8.9	3
Lakota	59.7	30.1	12.9	12.0	52.7	8.7	6
Stewart 63	62.8	39.8	12.4	11.5	55.5	7.9	5
Leeds	62.8	36.5	14.0	13.2	54.0	9.2	3

1/Perfect score 10.0.

Lakota, Stewart 63, and Leeds. These data show that Leeds is considerably better in test weight than either Wells or Lakota and the same as Stewart 63. In weight per 1,000 kernels, Leeds is much better than Wells or Lakota but lower than Stewart 63.

Small-scale, laboratory milling tests show that the semolina yield of Leeds is better than Wells and Lakota but not as high as Stewart 63. The color of the macaroni and spaghetti made from Leeds was consistently better

than either Wells or Lakota and considerably better than that produced from Stewart 63.

Wheat protein and semolina protein contents of Leeds are higher than any of the comparably grown varieties in this test. Although protein content in durum wheat is not as important from a quality standpoint as protein in bread wheat, it does give added protection for an adequate protein level if and when a low protein year occurs.

The gluten strength of Leeds semolina, as measured by the farinograph, was definitely weaker than either Lakota or Stewart 63, and about equal to Wells. Using experimental laboratory processing equipment and also continuous processing on a semicommercial scale using a vacuum press, excellent spaghetti was produced from all varieties without any important changes in the processing being made.

It is expected that when Leeds reaches commercial production, in about another year, it will prove to be a major advancement for durum wheat from both an agronomic and quality standpoint.

Production and Utilization

Table 6 shows the durum wheat production for North Dakota for the

Table 6.--Durum wheat production[1/]

Year	Yield, bu./acre	Increased yield basis, % 1920	1950	Production, million bushels	Acreage, million acres
1920	9.2	100	--	30.5	3.3
1925	14.0	152	--	43.0	3.1
1930	12.3	134	--	37.4	3.0
1935	10.5	114	--	18.1	1.7
1940	10.5	114	--	24.9	2.4
1945	16.5	179	--	29.9	1.8
1950	13.5	147	100	32.4	2.4
1955	13.0	141	96	12.7	1.0
1960	21.0	228	156	26.9	1.3
1965	31.5	342	233	61.0	1.9
1967	24.0	261	178	56.9	2.5

1/North Dakota Crop and Livestock Reporting Service, USDA.

years 1920 through 1967. The column showing the increased production per unit area of land is very interesting. For example, in 1920, 3.3 million acres of land produced 30.5 million bushels of durum; whereas, in 1965, 1.9 million acres of land produced 61.0 million bushels. Since 1950, the yield of durum wheat has increased 133 percent; if one were to compare the 1965 durum yield with that of 1920, the increase amounts to 242 percent.

Durum wheat is the only wheat class in the United States to show a yearly increase in per capita consumption. In 1947, the consumption of macaroni products in the United States was 5.8 pounds per capita. In 1954, this dropped to 5.6 pounds, but rose again in 1958 to 5.9 pounds. Since

then, a steady increase has been reported. The latest figures which are for 1966 place the per capita consumption at about 7.2 pounds.

Summary

In summary, it might be of interest to cite the various major steps of significance, represented by both the North Dakota wheat crops. Data below shows these steps for the hard red spring wheat.

Red Fife	1870 to 1915
Bluestem	1890 to 1915
Marquis	1912 to 1930
Ceres	1925 to 1938
Thatcher	1934 to 1945
Rival	1939 to 1950
Mida	1944 to 1955
Lee	1951 to 1956
Selkirk	1955 to --
Justin	1962 to --
Chris	1966 to --

Data below shows the important durum varieties. Of course, there were

Arnautka	1900 to 1918	18 yrs.
Kubanka	1900 to 1925	25 yrs.
Mindum	1917 to 1945	29 yrs.
Stewart	1943 to 1956	14 yrs.
Sentry	1954 to 1958	4 yrs.
Langdon	1956 to 1962	7 yrs.
Lakota	1960 to --	7 yrs. +
Wells	1960 to --	7 yrs. +
Stewart 63	1964 to --	3 yrs. +
Leeds	1966 to --	

many other HRS and durum wheat varieties grown in the upper Great Plains which were not discussed because in most instances these wheats received only limited acceptance.

Various rust epidemics were possibly the prime reason for the changes that necessitated the development of new varieties. Among the various advantageous factors that stand out from this changing picture were successive increases in yield of bushels per acre combined with resultant better overall quality of the flour or semolina milled from these wheats. Not only has the grower benefited from this varietal development program but industry also has an improved raw material for processing.

ATTENDANCE LIST

Paul E. R. Abrahamson
North Dakota State Wheat Commision
316 North Street
Bismark, North Dakota 58501

Mark F. Adams
College of Engineering
Washington State University
Pullman, Washington 99163

H. R. Albrecht
North Dakota State University
Fargo, North Dakota 58102

Wayne B. Allen
Nebraska Wheat Growers Association
McCook, Nebraska 69001

D. G. Amstutz
Spring and Durum Wheat Merchandising
Cargill, Inc.
Minneapolis, Minnesota 55415

Don Anderson
North Dakota State University
Fargo, North Dakota 58102

Emil Anderson
North Dakota State Wheat Commission
Upham, North Dakota 58789

Gerry Anderson
DeKalb Agricultural Association
Fargo, North Dakota 58102

I. M. Atkins
Texas A & M University
College Station, Texas 77843

Orville J. Banasik
North Dakota State University
Fargo, North Dakota 58102

B. E. Barker
Colorado Milling & Elevator Company
Twin Falls, Idaho 83301

McDonna Barsness
North Dakota State University
Fargo, North Dakota 58102

Richard K. Baum
Western Wheat Associates, USA, Inc.
Portland, Oregon 97205

W. G. Bechtel
American Institute of Baking
400 East Ontario Street
Chicago, Illinois 60611

Howard C. Becker
Nebraska Consolidated Mills Company
1521 North 16th Street
Omaha, Nebraska 68110

John H. Becker
Kansas Wheat Commission
1021 North Main
Hutchison, Kansas 67501

R. Keith Berg
North Dakota State Wheat Commission
1805 Hannaford Avenue
Bismark, North Dakota 58501

Charles P. Berry
North Dakota State University
Fargo, North Dakota 58102

Gordon P. Boals
Millers' National Federation
National Press Bldg.
Washington, D.C. 20004

Walter Bushuk
University of Manitoba
Winnipeg 19, Manitoba, Canada

Stuart Butler
Maple Leaf Mills, Ltd.
417 Queen's Quay West
Toronto, Ontario, Canada

Wren Case
Oregon Wheat Commission
Box 400
Pendleton, Oregon 97801

Robert Crawford
North Dakota State University
Fargo, North Dakota 58102

B. G. Crewdson
Upper Midwest Council
950 Federal Reserve Bank Bldg.
Minneapolis, Minnesota 55440

Lavoy I. Croy
Oklahoma State University
Stillwater, Oklahoma 74075

Hal M. Culpepper
Colorado Wheat Adm. Committee
1636 Welton Street
Denver, Colorado 80202

Leland Dahle
Peavey Company Flour Mills
Box 2111 Commerce Station
Minneapolis, Minnesota 55415

Bert D'Appolonia
North Dakota State University
Fargo, North Dakota 58102

William G. DeWitt
Corn Industries Research Foundation
1001 Connecticut Avenue, NW.
Washington, D.C. 20036

R. J. Dimler
Northern Regional Research Laboratory
ARS, USDA
Peoria, Illinois 61604

Alvin W. Donahoo
Minneapolis Grain Exchange
Minneapolis, Minnesota 55415

N. H. Eddy
Corn Products Company
717 5th Avenue
New York, New York 10022

Lewis H. Edwards
Oklahoma State University
Stillwater, Oklahoma 74074

Frank Ellis
Food for Freedom Service
Office of War on Hunger
Agency for International Development
Department of State
Washington, D.C. 20523

Robert V. Enochian
ERS, USDA
P.O. Box 89
Berkley, California 94701

L. E. Evans
University of Manitoba
Winnipeg 19, Manitoba, Canada

Helen C. Farnsworth
Food Research Institute
Stanford University
Stanford, California 94305

David A. Fellers
Western Regional Research Laboratory
ARS, USDA
800 Buchanan Street
Albany, California 94710

Robert G. Friese
Krause Milling Company
P.O. Box 1156
Milwaukee, Wisconsin 53055

E. F. Garner
The Pillsbury Company
116 3rd Avenue, S.E.
Minneapolis, Minnesota 55414

John Giertz
Kansas Milling Company
P.O. Box 2152
Wichita, Kansas 67201

Mearl Gifford
Great Plains Wheat, Inc.
Kansas City, Kansas 64100

K. A. Gilles
North Dakota State Universtiy
Fargo, North Dakota 58102

Ray C. Gralow
Corn Products International
717 5th Avenue
New York, New York 10022

R. M. Green
National Macaroni Manufacturers Assoc.
Palatine, Illinois 60067

Wm. L. Haley
Fisher Flouring Mills Company
3235 16th Avenue, SW.
Seattle, Washington 98124

Scott Hanson
Washington Wheat Commission
409 Great Western Bldg.
Spokane, Washington 99201

J. H. Hartley
Doane Agricultural Service, Inc.
2127 South Minnesota Avenue
Sioux Falls, South Dakota 57105

Ed Hawes
Kansas Wheat Commission
1021 North Main
Hutchinson, Kansas 67501

A. G. Hazen
North Dakota State University
Fargo, North Dakota 58102

Hjartor Hjartarson
Montana State Farm Bureau
Box 1207
Bozeman, Montana 59715

Jerry Holland
DeKalb Agricultural Association
Box 785
Fargo, North Dakota 58103

John Holme
The Ogilvie Flour Mills Company
Ltd., Research Division
995 Mill Street
Montreal, Quebec, Canada

William J. Hoover
Kansas State University
Manhattan, Kansas 66504

R. L. Hotchkiss
Dow Chemical
2020 Bldg. A.R.C.
Midland, Michigan 48640

Robert Huffman
North Dakota State Wheat Commission
Regent, North Dakota 58650

C. Robert Ivey
Multi-Grind Ltd.
81 Howden Road
Toronto, Canada

Clark Jenkins
Merchants National Bank
Fargo, North Dakota 58102

O. B. Jesness
University of Minnesota
Minneapolis, Minnesota 55404

Freeman Johnson
Cargil, Inc.
RR 2
Glyndon, Minnesota 56547

Paul E. Johnson
AID State Department
9715 Braddock Road
Fairfax, Virginia 22030

David R. Johnston
Cargill, Inc.
RR 2
Glyndon, Minnesota 56547

W. R. Johnston
International Milling Company, Inc.
1423 South 4th Street
Minneapolis, Minnesota 55404

Lloyd R. Jones
North Dakota State Wheat Commission
Palermo, North Dakota 58769

Myron Just
Dakota Farmer
Aberdeen, South Dakota 57401

Al Kenner
U.S. Durum Growers Association
Leeds, North Dakota 58346

Constance Kies
University of Nebraska
309 Food and Nutrition
Lincoln, Nebraska 68508

G. O. Kohler
Western Regional Research Laboratory
ARS, USDA
800 Buchanan Street
Albany, California 94710

John Konecny
Centennial Mills
Portland, Oregon 97208

Leonard Kresoya
General Mills, Inc.
9200 Wayzata
Minneapolis, Minnesota 55426

Howard H. Lampman
Millers' National Federation
Wheat Flour Institute
309 West Jackson Boulevard
Chicago, Illinois 60606

Kenneth Lebsock
North Dakota State University
Fargo, North Dakota 58102

Vernon C. Lee
Greater North Dakota Association
Fargo, North Dakota 58101

Matthew Lin
North Dakota State University
Fargo, North Dakota 58102

J. P. Littlejohn
Kellog Company
Battle Creek, Michigan 49016

Harry J. Loving
Mennel Milling Company
P.O. Box 189
Fostoria, Ohio 44830

Karl Lucken
North Dakota State University
Fargo, North Dakota 58102

Robert Maneval
North Dakota State University
Fargo, North Dakota 58102

C. L. Mast, Jr.
Millers' National Federation
14 East Jackson Boulevard
Chicago, Illinois 60604

Paul J. Mattern
University of Nebraska
205 Seed Laboratory Bldg.
Lincoln, Nebraska 68503

Clarence McDonald
North Dakota State University
Fargo, North Dakota 58102

Ralph B. McEwen, Jr.
Oregon Wheat Commission
Box 400
Pendleton, Oregon 97801

R. C. McGinnis
University of Manitoba
Winnipeg 19, Manitoba, Canada

Charles McGuire
North Dakota State University
Fargo, North Dakota 58102

M. R. McRoberts
Food and Agr. Organization of U.N.
1325 C. Street, SW.
Washington, D.C. 20437

Dale K. Mecham
Western Regional Research Laboratory
ARS, USDA
800 Buchanan Street
Albany, California 94710

Paul Menge
Northrup King and Company
1500 Jackson Street, NE.
Minneapolis, Minnesota 55413

Clarence B. Moore
Northern Regional Research Laboratory
ERS, USDA
Peoria, Illinois 61604

Glen A. Murray
University of Idaho
Moscow, Idaho 83843

Paluri R. Murthy
Peavey Company Flour Mills
Box 2111 Commerce Station
Minneapolis, Minnesota 55415

Carl W. Naessig
South Dakota Wheat Commission
409 East 12th Avenue
Webster, South Dakota 57274

Charles A. Nelson
North Dakota State Wheat Commission
P.O. Box 956
Bismark, North Dakota 58103

Dave Nelson
North Dakota State University
Fargo, North Dakota 58102

Cameron B. Newell
Cargill, Inc.
Minneapolis, Minnesota 55402

J. M. Newton
Clinton Corn Processing Company
Clinton, Iowa 52732

Bob Nixon
Oregon Wheat Commission
Box 400
Pendleton, Oregon 97801

E. R. Pariser
Avco Corporation
201 Lowell Street
Wilmington, Massachusetts 01887

C. W. Pence
Great Plains Wheat, Inc.
New Brotherhood Bldg., Suite 292
Kansas City, Kansas 66101

James W. Pence
Western Regional Research Laboratory
ARS, USDA
800 Buchanan Street
Albany, California 94710

Donald W. Pitts
The Pillsbury Company
224 2nd Street, SE.
Minneapolis, Minnesota 55414

Fred Poats
ERS, ME Division, USDA
Washington, D.C. 20250

Floyd Poyzer
North Dakota State Wheat Commission
Amenia Seed and Grain Company
Amenia, North Dakota 58004

Daryl R. Pring
North Dakota State University
Fargo, North Dakota 58102

John C. Rankin
Northern Regional Research Laboratory
ARS, USDA
Peoria, Illinois 61604

Louis P. Reitz
CRD, CCRB, Wheat Invest., ARS, USDA
115 SO-P, Plant Industry Station
Beltsville, Maryland 20705

Gwinn F. Rice
Idaho Wheat Commission
Box 131
Hill City, Idaho 83337

Tom Ridley
North Dakota State Wheat Commission
Langdon, North Dakota 58249

Larry Robertson
Funk Bros. Seed Company
1300 West Washington
Bloomington, Illinois 61701

Tibor Rozsa
Bay State Milling Company
Winona, Minnesota 55987

Richard K. Saunders
U.S. Durum Growers Association
Doyon, North Dakota 58328

W. C. Schaefer
Northern Regional Research Laboratory
ARS, USDA
Peoria, Illinois 61604

George Schiller
Dixie Portland Mills
Arkansas City, Kansas 67005

John Schmitz
North Dakota State University
Fargo, North Dakota 58102

F. R. Senti
NCIUR, ARS, USDA
Washington, D.C. 20250

John W. Sharp
Ohio State University
2120 Fyffe Road
Columbus, Ohio 43210

J. A. Shellenberger
Kansas State University
Manhattan, Kansas 66504

John J. Sherlock
Millers' National Federation
14 East Jackson Boulevard
Chicago, Illinois 60604

William C. Shuey
North Dakota State University
Fargo, North Dakota 58102

L. D. Sibbitt
North Dakota State University
Fargo, North Dakota 58102

Suresh K. Sinha
North Dakota State University
Fargo, North Dakota 58102

Melvin S. Sjerven
The Southwestern Miller
164 Grain Exchange
Minneapolis, Minnesota 55415

Sandra Skarsaune
North Dakota State University
Fargo, North Dakota 58102

G. S. Smith
North Dakota State University
Fargo, North Dakota 58102

Gus Snyder
South Dakota Wheat Commission
115 East Sioux Avenue
Pierre, South Dakota 57501

H. Donald Spangler
Merck and Company
West Scott Avenue
Rahway, New Jersey 07065

Joe Sullivan
Colorado Wheat Adm. Committee
1636 Welton Street
Denver, Colorado 80202

Donald F. Sundberg
Fisher Flouring Mills Company
3235 16th Street, SW.
Seattle, Washington 98124

John W. Swanson
The Institute of Paper Chemistry
P.O. Box 1048
Appleton, Wisconsin 54911

GPO 808-415-12

J. C. Swinbank
State Department of Agriculture
620 Terminal Bldg.
Lincoln, Nebraska 68508

Raymond Tarleton
American Assoc. of Cereal Chemists
1955 University Avenue
St. Paul, Minnesota 55104

Diane Thompson
North Dakota State University
Fargo, North Dakota 58102

John R. Thomsen
Washington Wheat Commission
409 Great Western Bldg.
Spokane, Washington 99201

Russell Tkachuk
Grain Research Laboratory
190 Grain Exchange Bldg.
Winnipeg 2, Manitoba, Canada

Bert Tollefson, Jr.
American Corn Millers Federation
Washington, D.C. 20005

Otis Tossett
Lansford, North Dakota 58750

C. C. Tsen
American Institute of Baking
Chicago, Illinois 60611

Ray Urquidi
North Dakota State University
Fargo, North Dakota 58102

J. S. Wall
Northern Regional Research Laboratory
ARS, USDA
Peoria, Illinois 61604

David E. Walsh
North Dakota State University
Fargo, North Dakota 58102

Lawrence L. Warren
Archer Daniels Midland Company
Box 532
Minneapolis, Minnesota 55440

Jane Wills
North Dakota State University
Fargo, North Dakota 58102

Vernon L. Youngs
North Dakota State University
Fargo, North Dakota 58102

GPO 808-415-13

United States Department of Agriculture
Agricultural Research Service
Northern Utilization Research and
Development Division
1815 North University Street
Peoria, Illinois 61604

OFFICIAL BUSINESS